

Soil Survey

Morton County North Dakota

By

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This number is the last Soil Survey Report for the year 1936



UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Bureau of Plant Industry, Soils, and Agricultural Engineering
In cooperation with the
NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

How to Use THE SOIL SURVEY REPORT

FARMERS who have lived in one locality for a long time come to know about the soil differences on their own farms and on those of their immediate neighbors. What they do not know, unless a soil survey has been made, is how nearly their soils are like those at experiment stations or in other localities from which higher yields are reported. They do not know whether these higher yields are from soils like their own or from soils so different that they could not hope to get equally high returns, even if they adopted the practices followed in these other places. These similarities and differences among soils are known only after a map of the soils has been made. Knowing what kind of soil one has and comparing it with soils on which new developments have proved successful will remove some of the risk in trying new methods and varieties.

SOILS OF A PARTICULAR FARM

To find what soils are on any farm or other tract of land, locate it on the soil map, which is in the envelope inside the back cover. This is easily done by finding the township, section, and quarter section the farm is known to be in and locating its boundaries by such landmarks as roads, streams, villages, and other features.

Each kind of soil is marked with a symbol on the map; for example, all areas marked M₁ are of the same kind of soil. To find the name of the soil so marked, look at the legend printed near the margin of the map and find M₁. The color where M₁ appears in the legend will be the same as where it appears on the map. The M₁ means Morton loam. A section of this report (see table of contents) tells what Morton loam is like, for what it is mainly used, and some of the uses to which it is suited.

How productive is Morton loam? Find this soil name in the left-hand column of

table 5 and note the productivity ratings for the different crops in the columns opposite. This table gives ratings for all the soils of the county, so that the productivity of different soils may be compared. What is good management for Morton loam? For this information read in the section on Land Uses and Agricultural Methods, where management practices for this and other soils of the county are discussed.

SOILS OF THE COUNTY AS A WHOLE

If a general idea of the soils of the county is wanted, read the introductory part of the section on Soils. This tells where the principal kinds are found, what they are like, and how they are related to one another. Then study the detail soil map and the section on Generalized Maps of Soil Associations. Notice how different kinds of soils tend to be arranged in different localities. These patterns are likely to be associated with well-recognized differences in types of farming and land use.

A newcomer who considers purchasing a farm in the county will want to know about the climate as well as the soils; the types and sizes of farms; the principal farm products and how they are marketed; the kinds and conditions of farm tenure; kinds of farm buildings, equipment, and machinery; availability of schools, churches, highways, railroads, and water supplies; industries; and cities, villages, and population characteristics. This information will be found in the sections on Description of the County Surveyed, Climate, and Agriculture.

Students and others interested in how the soils of the county were formed and how they are related to the great soil groups of the world should read the section on Morphology and Genesis of Soils.

This publication on the soil survey of Morton County, N. Dak., is a cooperative contribution from the—

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SOIL SURVEY OF MORTON COUNTY, NORTH DAKOTA

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United States Department of Agriculture in cooperation with the
North Dakota Agricultural Experiment Station

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MORTON COUNTY lies on the Missouri slope of the Great Plains province. Much land is grazed because hot dry summer winds and lack of moisture during the growing season limit crop production. Raising livestock—cattle, hogs, and sheep—and growing wheat are the principal farm enterprises. Wheat is the main field crop. Coal mining is the most important nonagricultural industry. To provide a basis for the best agricultural uses of the land a cooperative soil survey was made by the United States Department of Agriculture and the North Dakota Agricultural Experiment Station.

DESCRIPTION OF THE COUNTY SURVEYED

Morton County is in the southwestern part of North Dakota (fig. 1). The approximate center of the county is about 30 miles west of the Missouri River and about 55 miles north of the South Dakota State line. The Missouri River forms the eastern boundary. Mandan, the county seat, is only a few miles across the river from Bismarck, the

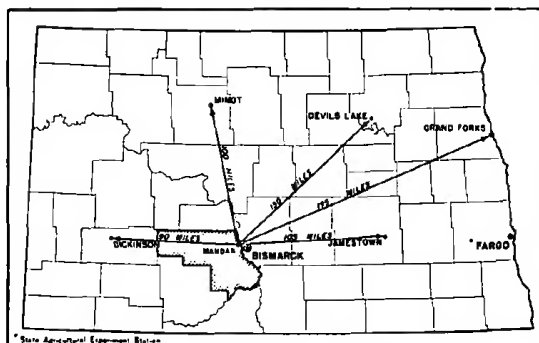


FIGURE 1.—Location of Morton County in North Dakota.

State capital, and about 200 miles west of Fargo, 105 miles west of Jamestown, 90 miles east of Dickinson, and 100 miles south of Minot. The total area surveyed is 1,933 square miles, or 1,237,120 acres.³

This county lies in that part of the Great Plains province designated as the Missouri Plateau. Locally, the region west of the Missouri River is more commonly known as the Missouri slope. This physiographic area is characterized by the dissection of a formerly smooth slope that drops from an elevation of approximately 2,400 feet above sea level in the western part of the county to about 2,150 in the eastern part. The entire area of Morton County is presumed to have been overridden by glacial ice (10, 11).⁴ Very little evidence of glaciation now exists in the southwestern half of the county. Throughout the remaining part glacial boulders are abundant, and in the extreme northeastern part numerous smooth upland areas are covered by a layer of olive-drab friable gravelly clay till that varies in depth from 2 to about 10 feet.

In general the lay of the land over much of Morton County is rolling. The roughest part is a strip extending 1 to 2 miles back from the Heart River and includes a narrower strip along the lower part of Sweetbriar Creek. For the most part, this particular area is rolling to steep, with numerous V-shaped valleys and coulees and narrow ridge tops. Most of this land is in grass. In places small tracts are suitable for tillage, and a limited acreage is cropped. The average difference in elevation between the valley floor and the ridges is about 280 feet. Several less extensive rough areas are a few miles east and southeast of Glen Ullin and south of New Salem. These areas also are strongly rolling with numerous steep slopes, but they do not lie as immediate slopes to a major stream valley. Scoria caps many of the narrow ridges in the rough areas to the south and east of Glen Ullin. The average elevation of the ridges above the valley floors in these areas is 150 to 200 feet. Other less regular and less extensive rough areas border the Missouri River valley and the Cannonball River valley.

There are a few comparatively smooth areas that range in size from a few hundred acres to several square miles. The land is undulating to gently rolling, and practically the entire acreage is tillable. Some of these areas occur as broad ridge tops, whereas others are undulating lowlands within broad drainage systems. The most important of these areas are Custer Flats, in T. 138 N., Rs. 81 and 82 W., and Bohemian Flats, in the southern part of T. 137 N., R. 84 W. Most of the upland part of the county is a mixture of irregular and comparatively small, smooth, tillable areas and rolling to strongly rolling areas broken in places by steep slopes. The distribution of these various topographic divisions is shown by the major color groups on the detailed soil map. Figure 2 is a small-scale map showing the general surface features and drainage of the county. The drainage system of Morton County is well developed. The drainage system in general is dendritic, with the drainageways spreading upward from the main stems toward

³ The soil survey of Morton County was made at the request of the local county authorities, in order to provide accurate data for the classification and evaluation of rural lands for local taxation purposes. The North Dakota Agricultural Experiment Station made up the land classification from the maps, and on completion of their tabulation these data were turned over to the county auditor's office for use as a basis for assessments. Funds were furnished by the county to pay for the State expense. An explanation of the land classification is given by Kellogg and Ablett (8).⁴

⁴ *Italic numbers in parentheses refer to Literature Cited, p. 158.*

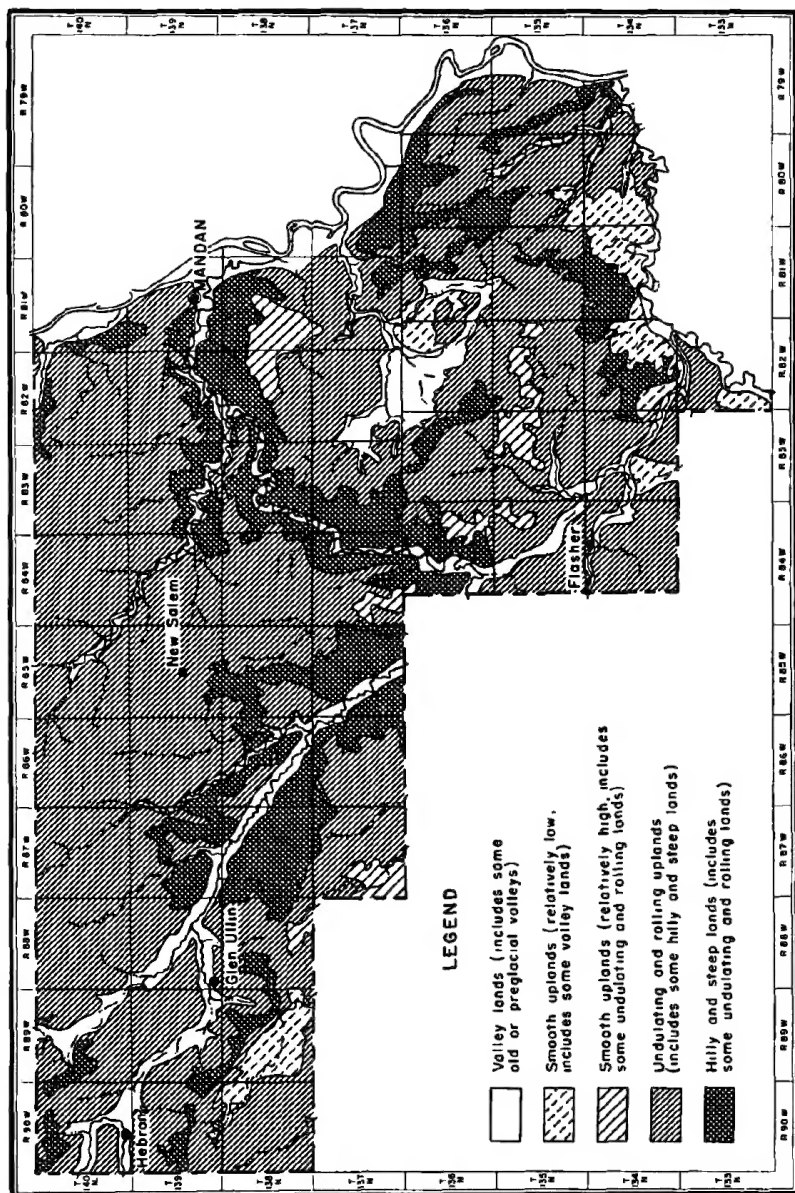


FIGURE 2—Principal drainage and surface features of Morton County, N. Dak.

the divides. All the county drains into the Missouri River, principally through the Heart, Cannonball, and Little Heart Rivers and Square Butte Creek (fig. 2).

The nearly level valley floor along the Missouri River ranges from less than one-eighth of a mile to approximately 3 miles in width. The lowest parts are poorly drained and are subject to occasional flooding in winter and spring. The average level of the first bottom land is about 18 feet above the river. The areas of the second bottom land are much more limited in total acreage. They lie as irregular, occasionally

broken strips about half a mile wide along the valley. This land slopes gently toward the river and lies about 30 feet above the general level of the first bottom lands. Drainage is good. The bottom lands along the Heart and Cannonball Rivers are about half a mile wide. (See pl. 11, A.) These valley soils are well drained, and only a small total acreage is subject to frequent inundation. The most extensive imperfectly drained areas are principally along the upper half of Muddy Creek valley and along the Little Heart River. These areas are nearly level flats of clayey soils. In general these soils are highly impregnated with salts but are not subject to frequent inundations. The elevations of various points throughout the county are as follows: Harmon 1,678 feet, Mandan 1,667 feet, Fort Rice 1,650 feet, New Salem 2,188 feet, Hebron 2,180 feet, and Antelope (in Stark County) 2,435 feet.

Morton County is composed of materials of the Fort Union, Lance, and Fox Hills formations. The Fox Hills formation is composed entirely of olive-gray or olive-drab marine sands that belong to the late Cretaceous system. The Lance and Fort Union formations are composed of beds of sands, silts, clays, and lignite that belong to the Tertiary system. All the Fort Union and the lower part of the Lance formations have been deposited by fresh water. The lignite beds vary in thickness from a few inches to several feet. Some of the beds are the source of a bountiful supply of fuel for local consumption. Remnants of a thin (10 to 18 inches) layer of gray, hard, dense shale that is generally broken to angular fragments occur here and there. The Fort Union formation occupies the western half of the county, the Lance formation most of the remaining part, and the Fox Hills formation a few square miles in the extreme southeastern corner. Olive-drab friable gravelly clay till covers most of the smooth upland areas in the northeastern part of the county. Throughout most of the county, clays and silts are the principal parent materials. In the southern part sands are the dominant parent material, with clays and silts of secondary importance.

The first white man to record his visit to this vicinity was David Thompson, a geographer and surveyor, who journeyed from the Mouse River valley in 1797 to visit the Mandan Indian villages at the mouth of the Knife River (12). Lewis and Clark reached a Mandan Indian village about 40 miles up the Missouri River from the present site of Mandan in 1804. Fur traders worked along the Missouri River before 1820. Fort Rice was established in 1864, and cattle migrations from the south to the northwest started about 1868. There were a few permanent ranches in this vicinity previous to 1873 (22). The Northern Pacific Railroad completed its main line through Morton County in 1873 and to the west coast in 1883. Settlement was more rapid following the extension of this railroad. Much of the area in the vicinity of Mandan was homesteaded by 1885. The most rapid homesteading took place, however, from about 1900 to shortly after 1910. According to the Federal census, 3.8 percent of the land was in farms in 1890, 13.3 percent in 1900, 43.7 percent in 1910, 87.3 percent in 1920, 90.2 percent in 1930, and 89.4 percent in 1940.

The county was organized in 1873. Its present boundaries were fixed in 1916. According to the Federal census, in 1940 the total population of the county was 20,184, 74.4 percent of which was rural. Mandan, the county seat, with a population of 6,685, is the largest municipi-

pality. Hebron, with a population of 1,348, is the only other municipality having a population of more than 1,000. Several other villages, some of which are organized, are scattered over the county and serve as trading centers and shipping points. Practically all of the arable land, and some land not generally suited as cropland, is utilized for the production of tilled crops. According to the land classification data for Morton County,^a the most extensive aggregate areas of land commonly accepted as cropland are (1) south from Mandan, including the vicinity of Saint Anthony, extending southwest by south to the vicinity of T. 136N., R. 82 W., thence westward to include the vicinity of Flasher; (2) north and northwest of Judson and New Salem; and (3) north, northwest, and west from Glen Ullin, extending to the Stark County line to include the vicinity of Hebron and to the south of that place. The two largest areas of uniformly tillable land are Custer Flats, a few miles south of Mandan, and Bohemian Flat, in the southern part of T. 138 N., R. 84 W. The distribution of the rural population corresponds with the distribution of the acreage of cropland. The population is most dense where the greatest percentage of the acreage of land is tilled. Few people live in the roughest areas, particularly those along the Heart River.

The people of Morton County came mostly from the northern part of Europe. According to the Federal census for 1940, the number of native whites is now 17,305, or 85.7 percent of the population, and the number of foreign-born whites is 2,850, or 14.1 percent. The rest is made up of 28 Indians and 1 Negro. The number that are either foreign-born or that have one or both parents of foreign birth is as follows: 6,454 (25) German Russians; 2,996 Germans; 1,662 Scandinavians; 692 Hungarians; 444 Austrians; and 358 Czechoslovakians. There are also some of French, English, Irish, Polish, Finnish, and Canadian origin. There is no sharp localization of nationalities, although certain ones are more prevalent in some localities than in others. People of German origin are more prevalent in the vicinities of New Salem, Glen Ullin, and Hebron, and Bohemians (Czechoslovakians) are somewhat more common south of Mandan and New Salem.

The Northern Pacific Railroad with its two branch lines affords convenient railroad shipping facilities to most of the county. Most of the towns and villages are within 16 miles of a shipping point, and very few are more than 20 miles. United States Highway No. 10 and several State highways afford good transportation throughout the year to all parts of the county. Most of the roads are improved, and parts of them are graveled. Automobiles can usually be driven easily to nearly all districts.

The principal farm products are shipped by rail and truck or by a combination of both. Wheat is handled by both private elevator concerns and farmer cooperatives. Minneapolis is the principal market, although a part is processed by mills within the State. Cattle, hogs, and sheep are marketed in Fargo and St. Paul. An occasional shipment of light hogs goes to the west coast. Livestock are marketed either through private dealers or cooperative organizations or by the owners. Dairy products, chiefly cream, are sold to creameries in Mandan and Bismarck. Poultry and eggs are either purchased by private

^a See footnote 3, p. 3.

buyers or handled by farmers' cooperatives. The principal markets are Chicago, St. Paul, and Minneapolis.

There are only a few small nonagricultural industries in the county. The principal ones are a brick factory at Hebron, a cement-tile factory at Schmidt, a coal (lignite) mine at New Salem, and a flour mill and creameries at Mandan. In addition to the large mine at New Salem, there are numerous smaller ones scattered throughout the county. These mines supply most of the fuel for local use, and the larger ones, particularly the one at New Salem, ship to points elsewhere in North Dakota and bordering States. As Mandan is located at a division point on the transcontinental line of the Northern Pacific Railroad and at a junction with two branch lines, it affords employment to shop-workers.

Rural school facilities are available in all parts of the county, although in some restricted areas they are not very convenient. High schools are at Hebron, Glen Ullin, New Salem, Flasher, and Mandan. Catholic and Protestant churches are located throughout the county, particularly in the larger villages.

CLIMATE

The climate of Morton County is typically semiarid and continental. It is characterized by long, severe winters and short, warm summers. The data from the records of the United States Weather Bureau station at New Salem are fairly representative of climatic conditions throughout the county. These data are given in table 1.

TABLE 1.—Normal monthly, seasonal, and annual temperature and precipitation at New Salem, Morton County, N. Dak.

[Elevation, 2,163 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1936)	Total amount for the wettest year (1915)
	^{°F}	^{°F}	^{°F}	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
December.....	15.3	62	-40	0.58	0.24	0.35
January.....	9.1	60	-43	.45	.60	.05
February.....	13.1	62	-45	.45	.91	.16
Winter.....	12.5	62	-45	1.48	1.75	.56
March.....	25.9	85	-28	.85	.74	.35
April.....	42.4	93	-3	1.04	.68	.95
May.....	52.4	100	11	2.12	.64	4.35
Spring.....	40.2	100	-28	4.01	2.06	5.65
June.....	62.9	108	29	3.47	.42	7.46
July.....	69.9	109	26	2.18	.04	5.38
August.....	67.2	104	30	1.82	1.18	1.34
Summer.....	66.7	109	26	7.47	1.64	14.18
September.....	57.5	104	14	1.36	.29	2.24
October.....	44.8	95	-10	.96	.13	2.10
November.....	29.8	76	-19	.49	.68	.57
Fall.....	44.0	104	-19	2.81	1.10	4.91
Year.....	40.9	109	-45	15.77	6.55	25.30

The temperature varies considerably throughout the year, and precipitation is irregular. Most of the precipitation falls in the early part of the summer. This is the important growing period for the crops commonly grown in this area, especially spring wheat. The mean annual precipitation of 15.77 inches is approximately one-half that of humid regions 500 miles farther east. Gradual darkening of the mature soils from west to east indicates indirectly a notable corresponding increase in rainfall, although available precipitation data do not correlate exactly with this observation. Investigations in the northern Great Plains by Cole, Mathews, and Chilcott (1) with spring wheat indicate that, even though the moisture conditions of the soil previous to spring sowing is important, the quantity of available water that may be stored in the soil at this time is not sufficient itself to meet the needs of the crop. The greatest consumption of water by spring wheat is at the time when the crop is approaching maturity. According to this publication there are four types of seasons relative to the development of this crop: (1) Seasons when sufficient moisture is available to the plants throughout their growth. This condition is rare in the area including Morton County. (2) Seasons when the moisture supply is sufficient only to carry the crop nearly to maturity. Such a circumstance brings about forced ripening and consequently a somewhat lower yield. The quality of the wheat in this case, however, generally suffers but little. This situation is occasionally experienced but is hardly to be considered as common. (3) Seasons when droughty conditions begin near "heading" time. This condition brings about wilting or firing as well as forced ripening. This is a common experience in this area. (4) Seasons when at no time is there sufficient moisture for optimum growth, but by meager straw growth the crop may be enabled to reach maturity and by timely rains make a low yield. Only occasionally does lack of moisture cause a complete crop failure.

The late summer and fall months are comparatively dry. This condition is desirable for the harvesting and preservation of crops left unprotected in the field, but severe on grass and legume seedlings, and frequently prevents the successful germination of fall-sown cereals. In general spring crops do best on the soil that has a good supply of moisture in storage when spring tillage begins. Winter precipitation generally, though not always, benefits the soil in this respect to an appreciable degree. The comparatively dry fall and winter weather is beneficial to the range forage. As the grazing vegetation does not deteriorate greatly from the effects of precipitation, it commonly affords good grazing throughout the fall and winter when protected from summer grazing. In fact, there have been occasional dry summer seasons during which the previous summer's growth has effectively supplemented the meager growth of the current season.

The average frost-free season extends from May 19, the average date of the latest killing frost, to September 20, the average date of the earliest, a period of 124 days. Generally the temperature is moderate until about July 1, after which frequent short, hot periods are experienced until the latter part of August. The long hours of daylight, combined with a fair quantity of precipitation and moderately warm temperature from May 1 to July 1, are favorable for the development of grasses and cereal crops. Because of the cool late spring season and dry late summer, only the earliest maturing varieties of corn are suitable for this area.

There are several crop hazards caused or augmented by weather conditions. Lack of moisture during the growing season is one of the most serious, and hot, dry winds during the early summer frequently cause considerable damage to the crops. Intermittent periods of rain interspersed with hot days favor the development of black stem rust, which is extremely damaging to the wheat crop. The number of grasshoppers is determined to a considerable extent by weather conditions. Cool, moist weather is very destructive to the young grasshoppers during the early growing season.

Owing to low humidity and low total precipitation during the winter season, it is possible for livestock to remain on the range for a great part of the year. Where the lay of the land affords protection from wind and storms, most of the horses and a great many cattle remain on the range throughout the winter. Additional protection and feed are required during severe storms or when the snowfall prevents grazing.

Much of the rainfall during the summer comes as local thunder-showers. Occasionally they reach the proportion of cloudbursts and thus cause considerable damage locally to young crops and to the soil by erosion. Under similar conditions severe local hailstorms frequently take place and may completely ruin crops. During the spring and fall months winds of high velocity sometimes cause severe soil blowing in places and offer considerable interference and some hazard to farm work.

VEGETATION ^a

The native grass vegetation of Morton County consists of mixed tall and short grasses, the latter by far predominating. The most common species growing on the smooth heavy soils of the uplands are blue grama, western wheatgrass, and needlegrass. Niggerwool, sandgrass, and some blue grama grow on the sandy areas. Little bluestem and niggerwool are common on exposed knobs and steeper slopes, and saltgrass grows in areas where there is an accumulation of salts. Sedges and weeds grow on the poorly drained areas and cattail in the wet areas.

Natural forest is confined to parts of bottom lands along the larger streams, narrow strips along drainageways, and to clumps or copse on the stronger north-facing slopes. The forest cover on the steep-sided gullies, especially those sloping to the north, is principally ash and elm, with some quaking aspen. The oaks are confined mostly to the eastern edge of the county, although a few are as far west as Glen Ullin. Other trees common to the area are chokecherry, wild plum, and boxelder. Shrubby growth common to this area is buckbrush, wild rose, buffaloberry, juneberry, hawthorn, gray sagebrush, pasture sagebrush, saltbush, and creeping cedar. Other plants are winterfat and pricklypear.

Before settlement by the white man, the bottom lands along the Missouri River were occupied by extensive groves of cottonwood, individual trees of which reached a diameter of about 30 inches. Other trees common to these bottom lands are ash and willow. Cottonwood

^aThe plants mentioned in this publication were identified by H. C. Hanson, botanist at the North Dakota Agricultural Experiment Station when this survey was made. The botanical names were verified so far as possible by C. O. Erlanson, ecologist, Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

trees are also common in the Cannonball and Heart River valleys, where they generally form a belt or strip along the sandy banks or natural levees. A few small tracts of virgin cottonwood fringe the courses of the other larger streams of the county. Much of the cottonwood timber has been cut for fuel and building material. At the present time the cottonwood growth is composed of trees that have grown since the virgin cover was removed. Much of the forest growth on the first-bottom lands of the Missouri River valley consists of young cottonwood, ash, and several species of willow. Extensive areas are also occupied by a dense growth of underbrush consisting principally of buckbrush, alder, wild rose, buffaloberry, and dogwood.

Forest products are utilized to a limited extent. According to the Federal census, the value of forest products sold in 1939 was \$376. Cottonwood is used for the construction of buildings on farms, and ash and diamond willow are used for poles and fence posts. Very little wood is used for fuel, because of its scarcity and the ease with which lignite can be obtained for this purpose.

On large areas the natural grass cover is being destroyed as the result of cultivation, and the stand on many remaining areas has been noticeably changed by overgrazing. Many areas where western wheatgrass was once dominant are now occupied principally by blue grama, and often the stand of pasture sagebrush has increased considerably. Such desirable grazing vegetation as winterfat and saltbush are easily eradicated as a result of continuous overgrazing. After a combination of drought and overgrazing, such as took place in 1934, wild onion, lambsquarters, and other weeds encroach on the pastures, particularly on the more fertile soils. Unless too severely suppressed, however, the natural grasses tend to recover their natural stand when normal moisture and less severe grazing conditions return. In some places prairie dogs have been responsible for the partial destruction of the grass cover. The fresh earth of the mounds covers a large part of the surface, and these animals also consume considerable grass. In very dry years much of the sod in the vicinity of the burrows is destroyed by their activities. After the return of normal rainfall these areas are covered by a dense growth of weeds. In this part of North Dakota the number of prairie dogs has decreased during recent dry years. Poisoning and probably starvation have been largely responsible.

A list of plants found in the county follows.

GRASSES AND SEDGES—continued

Scientific name	Common name
<i>Agropyron pauciflorum</i> (Schwein.) Hitchc. (A. <i>tenerum</i> Vasey).	Slender wheatgrass.
<i>Agropyron repens</i> (L.) Beaub.	Quackgrass.
<i>Agropyron smithii</i> Rydb.	Western wheatgrass, blue-joint, bluestem, bluestem wheatgrass.
<i>Agrostis alba</i> L.	Redtop.
<i>Andropogon furcatus</i> Muhl.	Bluejoint turkeyfoot, big bluestem.
<i>Andropogon hallii</i> Hack.	Turkeyfoot, sand bluestem.
<i>Andropogon scoparius</i> Michx.	Prairie beardgrass, little bluestem.
<i>Aristida longiseta</i> Steud.	Red three-awn, triple-awn grass.
<i>Avena fatua</i> L.	Wild oats.

GRASSES AND SEDGES—Continued

Scientific name	Common name
<i>Bouteloua curtipendula</i> (Michx.) Torr-----	Side-oats grama.
<i>Bouteloua gracilis</i> (H. B. K.) Lag-----	Blue grama.
<i>Bromus inermis</i> Leyss-----	Smooth brome.
<i>Beckmannia syzigachne</i> (Steud.) Fern. (B. erucaciformis (L.) Host of Am. Authors).	American sloughgrass.
<i>Buchloe dactyloides</i> (Nutt.) Engelm. (<i>Bulbilla dactyloides</i> Raf.).	Buffalo grass.
<i>Calamagrostis inexpansa</i> A. Gray (<i>C. americana</i> Scribn.).	Northern reedgrass.
<i>Calamovilfa longifolia</i> (Hook.) Scribn-----	Prairie sandgrass.
<i>Carex elcocharis</i> Bailey (<i>C. stenophylla</i> Wahl. of Am. Authors).	Upland sedge.
<i>Carex flifolia</i> Nutt-----	Threadleaf sedge, niggerwool.
<i>Dactylis stricta</i> (Torr.) Rydb-----	Desert saltgrass.
<i>Elymus canadensis</i> L-----	Canada wild-rye.
<i>Elymus macounii</i> Vasey-----	Macoun wild-rye.
<i>Hordeum jubatum</i> L-----	Foxtail barley, wild barley, squirreltail.
<i>Koeleria cristata</i> (L.) Pers-----	Junegrass, prairie junegrass.
<i>Muhlenbergia cuspidata</i> (Torr.) Rydb-----	Plains muhly.
<i>Poa palustris</i> L-----	Fowl bluegrass, false-redtop.
<i>Poa pratensis</i> L-----	Kentucky bluegrass.
<i>Poa secunda</i> Presl-----	Sandberg bluegrass.
<i>Puccinellia nuttalliana</i> (Schult.) Hitchc. (<i>P. airoides</i> Nutt.).	Nuttall alkali-grass, Zawadke's alkali-grass.
<i>Spartina pectinata</i> Link (<i>S. michauxiana</i> Hitchc.).	Prairie cordgrass.
<i>Sporobolus cryptandrus</i> (Torr.) A. Gray-----	Sand dropseed.
<i>Stipa comata</i> Trin. and Rupr-----	Needle-and-thread, western needlegrass, green porcupinegrass.
<i>Stipa spartea</i> Trin-----	Porcupinegrass.
<i>Stipa viridula</i> Trin-----	Green needlegrass, feathergrass.

TREES

<i>Acer negundo</i> L-----	Boxelder.
<i>Fraxinus lanceolata</i> Borkh-----	Green ash.
<i>Populus deltoides</i> Marsh-----	Cottonwood.
<i>Populus tremuloides</i> Michx-----	Quaking aspen.
<i>Prunus</i> sp-----	Wild plum.
<i>Prunus virginiana</i> L-----	Chokecherry.
<i>Quercus macrocarpa</i> Michx-----	Mossycup oak, bur oak.
<i>Salix interior</i> Rowlee-----	Water willow.
<i>Salix missouriensis</i> Bebb-----	Diamond willow.
<i>Ulmus americana</i> L-----	Elm.

SHRUBS, BRUSH, AND WEEDS

<i>Achillea millefolium</i> L-----	Common yarrow.
<i>Aenothera serrulata</i> Nutt. (<i>Merrioliz serrulata</i> (Nutt.) Walp.).	Tooth-leaved primrose.
<i>Agoseris glauca</i> (Pursh) D. Diets-----	Prairie dandelion.
<i>Ambrosia psilostachya</i> DC-----	Perennial ragweed.
<i>Amelanchier alnifolia</i> Nutt-----	Common serviceberry, juneberry.
<i>Artemisia cana</i> Pursh-----	Gray sagebrush.
<i>Artemisia caudata</i> Michx-----	Green sagebrush.
<i>Artemisia dracunculoides</i> Pursh-----	False tarragon, green sagebrush.
<i>Artemisia frigida</i> Willd-----	Pasture sagebrush, little sagebrush.
<i>Artemisia gnaphalodes</i> Nutt-----	Cudweed or white sagebrush.
<i>Asclepias speciosa</i> Torr-----	Showy milkweed.
<i>Aster ericoides</i> L. (<i>A. multiflorus</i> Alt.)-----	Wreath aster or white prairie aster.
<i>Aster oblongifolius</i> Nutt-----	Aromatic aster.

SHRUBS, BRUSH, AND WEEDS—continued

Scientific name	Common name
<i>Aster plarimicoides</i> (Nees) Torr. and Gray	White upland aster.
<i>Astragalus pectinatus</i> Dougl.	Narrow-leaved milkvetch.
<i>Atriplex nuttallii</i> S. Wats.	Nuttall saltbush.
<i>Brassica kaber</i> var. <i>pinnatifidum</i> (Stokes) Wheeler (<i>B. arvensis</i> L.).	Wild mustard
<i>Campanula rotundifolia</i> L.	Harebell or bluebell.
<i>Cerastium arvense</i> L.	Starry cerastium or prairie chickweed.
<i>Chrysopsis villosa</i> (Pursh) Nutt.	Hairy golden-aster.
<i>Chrysothamnus nauseosus</i> var. <i>gracilentus</i> (Nutt.) Hall.	Rabbitbrush.
<i>Cirsium undulatum</i> (Nutt.) Spreng.	Prairie thistle.
<i>Conringia orientalis</i> (L.) Dum.	Hares-ear-mustard.
<i>Cornus stolonifera</i> Michx.	Red-osier dogwood.
<i>Coryphantha vivipara</i> (Nutt.) Britt. and Rose.	Bull cactus.
<i>Crataegus chrysoarpa</i> Ashe.	Hawthorn
<i>Delphinium virescens</i> Nutt.	Tall larkspur.
<i>Echinacea angustifolia</i> DC.	Purple coneflower.
<i>Elaeagnus utilis</i> A. Nels. (<i>Lepargyrea argentea</i> (Nutt.) Greene).	Silver buffaloberry.
<i>Eriogonum flavum</i> Nutt.	Yellow eriogonum.
<i>Eurotia lanata</i> (Pursh) Moq.	Winterfat.
<i>Gaillardia aristata</i> Pursh.	Common perennial gaillardia.
<i>Glycyrrhiza lepidota</i> Nutt.	Wild licorice.
<i>Grindelia squarrosa</i> (Pursh) Dunal.	Curlycup gumweed.
<i>Gutierrezia sarothrac</i> (Pursh) Britt. and Rusby.	Broom snakeweed.
<i>Hosackia americana</i> (Nutt.) Piper (<i>Lotus americanus</i> (Nutt.) Bisch.)	Prairie birdsfoot trefoil, birds-foot deerfatch, deerlover.
<i>Iva axillaris</i> Pursh.	Poverty weed.
<i>Juncus</i> spp.	Rush (several species).
<i>Juniperus horizontalis</i> Moench.	Creeping juniper, creeping cedar.
<i>Lactuca ludoviciana</i> (Nutt.) DC.	Western wild lettuce.
<i>Lactuca puchella</i> (Pursh) DC.	Blue wild lettuce
<i>Lappula occidentalis</i> (S. Wats.) Greene.	Low stickseed.
<i>Lepidium densiflorum</i> Schrad.	Peppergrass
<i>Liatris punctata</i> Hook.	Gayfeather, blazing-star.
<i>Liatris scariosa</i> (L.) Willd.	Gayfeather, blazing-star.
<i>Linum lewisii</i> Pursh.	Prairie flax, Lewis wild flax.
<i>Linum rigidum</i> Pursh.	Stiffstem flax, wild yellow flax.
<i>Lomatium daucifolium</i> (Nutt.) Coult. and Rose.	Wild parsley.
<i>Lygodesmia juncea</i> (Pursh) D. Don.	Skeletonweed.
<i>Mentha canadensis</i> L.	Wild mint.
<i>Mertensia lanceolata</i> (Pursh) DC.	Bluebell, wild forget-me-not.
<i>Monarda fistulosa</i> L.	Wildbergamot.
<i>Musineon divaricatum</i> (Pursh) Raf.	Tooth-leaved evening-primrose.
<i>Opuntia fragilis</i> (Nutt.) Haw.	Small pricklypear.
<i>Opuntia polyacantha</i> Haw.	Pricklypear.
<i>Oxytropis lamberti</i> Pursh.	Locoweed, crazyweed
<i>Penstemon albidus</i> Nutt.	White beardtongue.
<i>Penstemon criniticus</i> Pursh (<i>P. cristatus</i> Nutt.).	Crested beardtongue.
<i>Penstemon gracilis</i> Nutt.	Slender beardtongue.
<i>Petalostemum oligophyllum</i> (Torr.) Rydb.	White prairie clover.
<i>Petalostemum purpureum</i> (Vent.) Rydb.	Purple prairie clover.
<i>Phlox hoodii</i> Richards.	Moss phlox
<i>Plantago purshii</i> Roem and Schult.	Wooly Indianwheat, prairie plantain
<i>Potentilla strigosa</i> Pall.	Prairie cinquefoil.
<i>Psoralea argophylla</i> Pursh.	Silverleaf scurfpea.
<i>Psoralea esculenta</i> Pursh.	Indian breadroot, Indian turnip, tipsin.
<i>Ratibida columnaris</i> (Sims) D. Don.	Long-headed coneflower
<i>Rhus rydbergii</i> Small.	Western poison-ivy.

SHRUBS, BRUSH, AND WEEDS—continued

Scientific name	Common name
<i>Rhus trilobata</i> Nutt.-----	Lemonade sumac, three-lobed sumac.
<i>Rosa woodsii</i> Lindl.-----	Woods rose, wild rose.
<i>Salicornia europaea</i> L. (<i>S. herbacea</i> L.)-----	Glasswort.
<i>Salsola kali</i> var. <i>tenuifolia</i> Tausch (<i>S. pestifer</i> A. Nels.)-----	Russian-thistle.
<i>Selaginella densa</i> Rydb.-----	Little clubmoss.
<i>Senecio perplezeus</i> A. Nels.-----	Ragwort.
<i>Setaria lutescens</i> (Weigel) F. T. Hubb. (<i>Chactochloa lutescens</i> Stuntz).-----	Yellow pigeongrass.
<i>Setaria viridis</i> (L.) Beauv. (<i>Chactochloa viridis</i> Scribn.)-----	Green pigeongrass.
<i>Sisymbrium altissimum</i> L.-----	Tumbling mustard.
<i>Solanum triflorum</i> Nutt.-----	Cut-leaved nightshade.
<i>Solidago canadensis</i> L.-----	Canada goldenrod.
<i>Solidago missouriensis</i> Nutt.-----	Early goldenrod.
<i>Solidago mollis</i> Bartl.-----	Soft goldenrod.
<i>Solidago nemoralis</i> Ait.-----	Old-field goldenrod.
<i>Solidago rigida</i> L.-----	Stiff goldenrod.
<i>Sphaeralcea coccinea</i> (Nutt.) Rydb. (<i>Malvas-trum coccineum</i> (Nutt.) A. Gray)-----	False-mallow.
<i>Steironema ciliatum</i> (L.) Raf.-----	Fringed loosestrife.
<i>Suaeda</i> sp. (<i>Dondia</i> sp.)-----	Seepweed.
<i>Symphoricarpos occidentalis</i> Hook.-----	Wolfberry, buckbrush.
<i>Teucrium occidentale</i> A. Gray.-----	Wood sage.
<i>Thermopsis rhombifolia</i> (Nutt.) Richards.-----	False lupine.
<i>Thlaspi arvense</i> L.-----	
<i>Triglochin maritima</i> L.-----	Arrowgrass.
<i>Verbena bracteosa</i> Michx.-----	Bracted vervain.
<i>Vicia sparsifolia</i> Nutt.-----	Wild vetch.
<i>Viola nuttallii</i> Pursh.-----	Nuttall violet.
<i>Yucca glauca</i> Nutt.-----	Soapweed yucca, beargrass.
<i>Zigadenus chloranthus</i> Richards.-----	Deathcamas

AGRICULTURE

The first agricultural activity in this area was the raising of beef cattle on the range. About 1868, cattlemen from Texas started annual spring migrations of herds to the northern Great Plains. This practice proved profitable, for the cattle responded remarkably well to the grazing of these areas. Owing in part to the increased difficulty of migrating, brought about through the settlement of the country through which the herds had to travel and to grazing difficulties on the northern range, this practice diminished from about 1885 and ceased entirely about 1889. Meanwhile fixed ranches developed in this area, and until herds became numerous there was generally sufficient grass to afford year-round grazing.

According to Bulletin 237 of the North Dakota Agricultural Experiment Station (4), the whole northern Great Plains region was fully stocked with cattle by 1885. The tendency to overstock, the encroachment of homesteaders, the increasing taxes, and the general failure on the part of cattlemen to build up winter feed reserves for emergencies caused by severe droughts and severe winter storms brought disaster to cattlemen at various times. The need for more careful ranch management has been recognized in recent years, and there has been a marked tendency to turn homesteads poorly suited to cropping back to a grazing status. By so doing more grazing land is being made available and the movement toward greater dependence

on livestock and less on cash-grain crops is helped. This general trend, though slow, is toward a more stable agriculture for the region.

Homesteaders seeking farm land came into Morton County shortly after the Northern Pacific Railway entered this area. At first the farmers grew wheat and flax as their main sources of income, and very soon these crops formed an important part of the total crop acreage. The acreage for such cash crops as wheat, flax, and rye increased until in 1929 it was approximately 60 percent of the total crop acreage. A few communities manifested an early interest in dairying, and a system of mixed farming was developed, with feed crops receiving considerable attention.

The acreage of tilled land showed a marked increase until about 1920, after which there was a less marked increase until after 1930. According to the 1940 census, in 1939 the threshed acreage of the cash crops, wheat, rye, and flax was approximately 46 percent of the total harvested cropland. Meanwhile, during the years prior to 1932 the number of cattle increased, owing, at least in part, to several successive years of depressed prices for beef cattle, when ranchmen preferred to hold their cattle instead of marketing them. The drought of 1934 reduced the carrying capacity of the already overcrowded range so much that most of the livestock producers found it necessary to dispose of the greater part of their herds. In 1936, another extremely dry year, the number of cattle was further reduced. Most of the decrease has come in the size of the herds rather than in any diminution in the number of herds. For example, among the farmers who practiced dairying, the number of cows milked per farm prior to 1930 (18 to 20 head) was reduced to a herd of perhaps 7 or 8 in 1936. With improvement in forage and grazing conditions, the number of cows for milk production increased from 13,749 in 1930 to 15,002 in 1940. The number of horses over 3 months of age on April 1, 1930, was 16,785, as compared with 10,648 on April 1, 1940.

The number of sheep also showed a marked increase during the decade 1920-30, followed by a decline during the drought of 1934, after which there was a gradual increase. According to the census, the number of sheep and lambs over 6 months of age on April 1, 1930, was 11,078, and on April 1, 1940, it was 12,338. The number of swine of all ages increased from 11,375 on January 1, 1920, to 18,635 on April 1, 1930. After this time there was a marked decrease; the census reported only 5,985 over 4 months of age on April 1, 1940. The number of chickens has shown the same general trend as that for cows, swine, and sheep. On January 1, 1920, the number of chickens was 96,375, and by April 1, 1930, the number over 3 months of age had increased to 119,246. On April 1, 1940, the number over 4 months of age had decreased to 95,270.

Acreages of the principal crops as reported by the Federal census at 10-year intervals are given in table 2.

The acreage of wheat increased until Government curtailment in 1934. Flax has shown a spasmodic fluctuation with a general tendency for the acreage to diminish. While the increasing acreage of wheat caused the acreage of cash crops to increase continually until 1929, the total acreage of feed crops increased only until 1919. The combined acreage of corn, oats (threshed and fed unthreshed), barley, sorghums, and all hay for 1939 was 165,460 acres, as compared with

TABLE 2.—*Acreage of the principal crops in Morton County, N. Dak., in stated years*

Crop	1889	1899	1909	1919	1929	1939
	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
Wheat.....	10,445	41,779	172,579	181,250	238,593	143,002
Barley.....	205	371	5,337	17,274	36,738	24,983
Oats.....	2,955	9,956	53,841	18,898	22,544	27,661
Corn (grain).....	2,590	4,030	12,321	9,384	7,422	15,416
Rye.....		310	170	38,222	7,032	809
Emmer and spelt.....			3,774	1,051	1,636	669
Flax.....	285	1,620	39,118	11,285	22,206	727
Potatoes.....	645	776	2,304	1,370	868	668
Hay.....	17,109	54,822	153,277	142,990	76,989	66,216
Alfalfa.....			33	2,413	3,681	1,209
Timothy and clover, alone or mixed.....			69	152	42	175
Clover alone.....				226	1,213	886
Small-grain hay.....		832	1,559	18,914	17,379	3,998
Other tame hay.....		1,711	2,741	9,225	2,790	26,400
Wild hay.....		52,279	148,875	112,060	51,884	33,548
Silage crops.....				542	1,261	1,427
Sorghums, all purposes except sirup.....					1,257	6,625
Forage crops.....		45	340	6,134	18,125	17,342

¹ Corn.

170,220 acres in 1929. Smaller acreages of all crops except sorghums, corn, and oats are reported in 1939 than in 1929. The acreage of wild hay is diminishing and undoubtedly will continue to do so. During recent years silage crops have become of some significance and the acreage of clovers (almost wholly sweetclover) has assumed some prominence, particularly on the Missouri River bottom land.

At present two general systems of agriculture are practiced in Morton County: (1) Ranching, and (2) mixed farming, with a cash crop, principally wheat, dominating. Either system is very seldom practiced to the exclusion of the other. The most important sources of income to farmers today are wheat, beef cattle, dairy products, poultry, hogs, sheep, including wool, and flax, in the order of their relative value. Ranching is practiced in the rougher parts of the county. The grazing areas afford feed for a great part of the year, and the limited arable areas are used for forage crops for winter feed, such as wild hay, grains cut green for hay, and corn forage. Generally a small acreage of wheat is raised as a cash crop.

Mixed farming is practiced in those parts of the county where a greater part of the acreage is arable. There are two principal types of mixed farming: (1) One in which the production of cash grain crops, such as wheat and flax, is supplemented by the raising of some animals for meat; and (2) one in which both dairy products and cash grain crops are produced. This system may or may not be supplemented by animals for meat. The first type of mixed farming is practiced generally in those sections where the smooth areas are most extensive, and the second type where the areas of arable land are more irregular or are broken by nonarable tracts. This general distribution is modified somewhat, however, by the inclinations of the individual farmers and by the local areas in which dairying has become established.

In recent years dairying has been markedly suppressed by the shortage of feed and grass. On a small dairy farm (5 to 10 cows) about 50 to 65 percent of the acreage of arable land is devoted to

cash crops, 15 to 20 percent to oats and barley for grain feed, 10 to 15 percent to corn and sorghum for grain and forage, and from 5 to 20 percent to other forage crops, such as grains cut green, and millet. Cattle are run on the range at the rate of 10 to 20 acres a head, depending on the length of the grazing season, seasonal precipitation, and the character of the land.

The principal breed of dairy cattle is Holstein-Friesian. Milking strains of Shorthorns are preferred by many who desire to have a source of income from both beef and dairy products. Purebred sires are commonly used by the better beef-cattle producers and dairymen. The most common breeds of beef cattle are Hereford, Shorthorn, and Aberdeen-Angus, with the Hereford the most common.

Beef cattle are generally marketed at the age of $1\frac{1}{2}$ to $3\frac{1}{2}$ years; probably $2\frac{1}{2}$ years is the most common. The market trend and price and the condition of the range have much to do with the age at which they are sold. When grazing areas are suitable for winter grazing, only the calves and breeding stock are fed regularly, while the rest of the herd is left on the range except during the severest weather. Animals to be sold are shipped direct from the range, and no feeding is done in preparation for the market.

Dual-purpose breeds of sheep are the most common. Most of them are in flocks of 200 to 300 or less. Most of the lambs are marketed as feeders in the late fall or early winter, and the wool is clipped from the first of May to the middle of June. Unlike the beef cattle, sheep are commonly fed throughout the winter.

The low and uncertain yield of corn, as compared with that obtained in other sections of the United States, is the principal factor limiting hog production in this area. Many of the hogs, particularly in recent years, are raised to be butchered on farms for home use. Corn and barley are the principal grains used for fattening hogs. Small grains and rape are the most common crops used for pasture.

Practically all farms have a flock of chickens ranging from 25 to 200 or 300. Barred Plymouth Rocks, Wyandottes, Rhode Island Reds, and White Leghorns are the most common breeds. Turkeys are increasing. According to the United States census, there were 6,333 turkeys on farms April 1, 1940. Except for the largest flocks, turkeys forage for their feed during the summer months. Most of the growers feed some grain for a month or so previous to marketing them. They are sold during the latter part of November and the first part of December.

Preparation of land for crops is done with comparatively large machinery. Plowing is done with tractors and with horses. Gang plows having from two to four bottoms are commonly used. Fall plowing is practiced on the clay loam heavy soils when the ground is moist enough. These heavy soils develop a better tilth when plowed in the fall, because of the effect of freezing and thawing on the clods. Owing to their weaker structure and consequently greater susceptibility to soil blowing, the more loamy and sandy soils are seldom plowed in the fall. Moreover, the plowed clods are easily broken to make a good seedbed without passing through the freezing and thawing of the winter and early spring seasons. Spring seedbed preparation, in contrast with that practiced in more humid regions, commonly leaves the ground rough and trashy. Soil preparation involves less

work and reduces the hazard of soil blowing. Although much of the acreage for seeding and planting is prepared by plowing and light disking, a considerable acreage for seeding is prepared only by disking; and when the ground is mellow, as it may be after a crop of corn, small grain is sometimes drilled in without any preparation of the seedbed.

The seeding of crops is begun as early in the spring as soil conditions allow, generally about April 1. Wheat is the first crop sown, and it is followed by oats and barley. Flax and corn are sown and planted, beginning about May 10, and potatoes at about the same time or a little later. Rye is a fall-sown crop. Hay crops, such as sweetclover, alfalfa, and slender wheatgrass, are generally though not always sown with nurse crops of wheat, rye, or barley.

Until recently (1941), crops requiring cultivation were usually taken care of by two-horse sulky cultivators, but a considerable part is now cultivated by power machinery. Such crops are cultivated from two to four times, depending on the quantity and distribution of rain, consequent weed growth, and the time available for the work.

The harvesting of grain crops is begun in the early part of July. Rye and barley are the first crops to mature, followed by oats and wheat. Oats require immediate cutting after maturing, because of the tendency to shatter; but the varieties of wheat grown will stand for several weeks without shattering if severe weather conditions do not develop. Flax is harvested in September. The harvesting of small-grain crops is done with binders, combines, and headers. If the crop is not harvested by combine, threshing is generally started about the middle of August and extends into September. Very little grain is stacked for threshing. Some farmers conserve their straw for bedding and feed; others either burn it or allow it to decay in the piles. The threshed grain to be sold is stored on the farms, hauled to the elevators to be stored, or sold immediately. Corn is generally harvested in early September, although harvesting dates vary according to season. The corn is cut, placed in shocks, and later stacked at a place convenient for feeding. Before cutting the crop some farmers snap the ears for winter grain feed for livestock and poultry.

Hay is generally stacked in the meadows, although a few farmers and ranchers haul it to the feeding corrals, to be either stacked or placed in barns. Sweetclover and alfalfa are cut during midsummer. If moisture conditions are favorable, a second cutting of these two crops is made about the last of August or the first of September. When small grains are used for hay, they are generally cut shortly before they reach maturity. Such crops as millet, sorgo (locally called cane), and wild hay are ordinarily cut during the early fall.

Some plan of crop rotation is practiced by many farmers. Most of them plan either to grow a cultivated crop or to summer-fallow their land every 3 or 4 years. The principal purpose of this practice is to avoid continuous small-grain crops and to keep the growth of weeds in check. It is the common opinion that growing corn or other cultivated crops is just as beneficial to the following crop as summer fallowing and provides an additional crop as well; whereas if summer fallowing is practiced the land lies idle. Moreover, if a crop is grown the ground is protected most of the season from the hazards of soil blowing. Moldboard plows, disk harrows, and duckfoot cultivators are the most

common implements used for summer fallowing. The fallowed ground is left as rough or cloddy as possible, in order to minimize soil blowing, as the coarser textured soils, such as the very fine sandy loams, sandy loams, and fine sands, are especially susceptible to blowing. Areas having a bumpy or rolling surface are also particularly subject to soil blowing when summer fallowed.

One of the most common rotations used is a 3- or 4-year plan involving one crop of corn followed in sequence by 1 or 2 years of wheat and 1 year of barley or oats. If meadow is to be established, the seed is sown with the wheat or barley. When once established, tame-grass meadow is generally left as long as it produces fairly well. Grass seedlings are usually difficult to establish, owing to frequent dry summers and to heaving frost during the fall, winter, or early spring. Flax is generally sown following a cultivated crop or summer fallow, because of the ease with which weeds outstrip it when they are in competition. Although crop rotation of some sort is commonly practiced, many farmers still sow small grains, especially wheat, year after year in the same field. In general, however, a marked improvement in farming practices, as to rotations, tillage methods, and strip cropping, has been evident in recent years.

All the wheat is spring sown, and most of it is hard red spring wheat. In the early years of wheat growing Marquis was the most popular variety. It was gradually replaced by Ceres until 1935, when the black stem rust epidemic did serious damage to Ceres wheat. Thereafter there was a general decline in the acreages of both the Marquis and Ceres varieties and a replacement by the more rust-resistant Thatcher variety. A few farmers are still growing miscellaneous varieties.

During the period 1911-26 the acre yield for wheat harvested in this county averaged 9.3 bushels and ranged from 3 bushels in the worst year to 17 bushels in the best year; whereas during the period 1929-36 it averaged 7.5 bushels for spring wheat other than durum and ranged from 2.0 bushels in 1936 to 12.4 bushels in 1932.⁷

The North Dakota Agricultural Experiment Station has conducted continuous comparative trials on a number of these hard red spring wheats at the Dickinson substation in Stark County. During the period 1930-39, Thatcher wheat yielded 10.8 bushels an acre, Marquis 9, Ceres 11, Red Fife 7.6, and Haynes Bluestem 7.4. In a more recent 5-year comparison (1935-39) Thatcher yielded 11.1 bushels an acre, Marquis 7.7 bushels, Ceres 9.4 bushels, Red Fife 5.3 bushels, Haynes Bluestem 5 bushels, Pilot 11.9 bushels, and Rival 12.2 bushels. Thatcher, Pilot, and Rival have greater resistance to rust than any other wheat.⁸

Very small acreages are planted to durum wheats; consequently, some reference to comparative yields of durum and hard red spring wheats, where tests are made under comparable conditions, should be of interest. During the period 1923-37, excluding 1936 because of total crop failure, the following comparable acre yields were obtained at the Dickinson substation: Durum wheats—Kubanka, 14.5 bushels; Min-dum, 13.1 bushels; and Pentad (D-5), 14.5 bushels. Hard spring

⁷ All data concerning yields during the period 1911-26 mentioned throughout this report are taken from North Dakota Agricultural Experiment Station Bulletin 212 (24), and all data concerning yields during the period 1929-36 are taken from the records of the Division of Agricultural Statistics, Agricultural Marketing Service, U. S. Department of Agriculture.

⁸ For further information on testing spring wheat, see bulletins by Ralph W. Smith (17, 18).

wheats—Marquis, 13.3 bushels; Ceres, 15.9 bushels; Red Fife, 12.2 bushels; and Haynes Bluestem, 11.9 bushels.⁹

Flax is the second most important cash crop, but the acreage has diminished in recent years. It is necessary to grow wilt-resistant varieties. According to the North Dakota Agricultural Experiment Station, Buda and Bison are the best two varieties for North Dakota. Flax fits in well with wheat farming because it is sown and harvested later than wheat. The greatest difficulty in the production of this crop is control of weeds. Flax grows slowly during the first few weeks of its development, and its comparatively thin foliage allows weeds to overtake it easily. Ground free from weeds, therefore, is favored for this crop. Soil blowing on some soils causes serious damage during the early period of growth, because of the lack of foliage and roots to protect the surface soil from being blown away.

The yield during the period 1911–26 averaged 6.1 bushels an acre and ranged from 1.5 to 11.5 bushels. During the period 1929–36 the yield averaged 3.3 bushels an acre and ranged from failure in 1936 to 5.3 bushels in 1935.

Average acre yields of wilt-resistant varieties of flax at the Dickinson substation over the period 1928–39 (excluding some years because of total failure owing to drought, damage from black stem rust, and damage from grasshoppers) were as follows: Bison, 4.4 bushels; Buda, 3.2 bushels; Linota, 3.9 bushels; North Dakota Resistant 114, 3.5 bushels; Redwing, 4.1 bushels; and Rio (L-79), 4.3 bushels. Over the same period average acre yields at the Northern Great Plains Field Station, Mandan, N. Dak., were as follows: Bison, 5.7 bushels; Buda, 4.8 bushels; Linota, 5.1 bushels; Redwing, 4.7 bushels; and Rio (L-79), 5.2 bushels.¹⁰

Rye is a minor cash crop. It is well suited to the sandy soils, however, and fits well in a crop rotation for such soils. It is fall sown and under favorable conditions can be used for spring pasture. In recent years the fall seasons have been too dry to germinate the seed before winter weather sets in. Because of its thin foliage and early maturity, it makes a good nurse crop for grass and clover seedings. The average yield over the 16-year period 1911–26 was 12.5 bushels an acre, and the range was 3 to 31 bushels. During the 8-year period 1929–36 the average yield was 8.8 bushels, and the range was from failure in 1934 and 1936 to 11.5 bushels in 1935.

Barley is the most important grain feed crop. None, however, is grown for the malting industry. It matures somewhat earlier than oats, and its water requirement per hundred pounds of dry weight is lower than that of oats. It is also a more satisfactory feed for fattening animals for meat, particularly hogs. During recent years, when other forage crops were not plentiful or when the prospect for a grain yield was poor, the barley was cut for hay. It is also used with other small grains or with grasses or rape for pasture, particularly for hogs. According to the North Dakota Agricultural Experiment Station, Trebi is the most satisfactory variety for this area (20). The annual yield during the 16-year period 1911–26 averaged 18.1 bushels an acre and ranged from 2 to 32.4 bushels; whereas during the period 1929–36

⁹ STOA, T. E., and others. YIELDS FROM SMALL GRAIN VARIETY TESTS. N. Dak. Agr. Expt. Sta. Agron. Mimeo. Cir. 66, 32 pp. 1937. [Processed.]

¹⁰ STOA, T. E., and others. YIELDS FROM SMALL GRAIN VARIETY TRIALS IN NORTH DAKOTA. N. Dak. Agr. Expt. Sta. Agron. Mimeo. Cir. 70, 30 pp. 1939. [Processed.]

it averaged 13.3 bushels and ranged from 3.0 bushels in 1936 to 21.5 bushels in 1935.

Oats are widely grown, but the acreage until recently has not been as great as that of barley. The grain is especially good for work animals during the seasons when they are being used. Oats are also the most satisfactory of the grain crops for hay, and the straw is the best of any of the grain straws for roughage, as the forage is more palatable and the yield to the acre is higher than for either barley or wheat. According to the North Dakota Agricultural Experiment Station (21), Gopher and Loggold are the most satisfactory varieties for this area. Yields range from 1 to 41.8 bushels an acre, with an average, over the 16-year period 1911-26, of 23.3 bushels. The range over the 8-year period 1929-36 was from failure in 1936 to 27.4 bushels in 1935. The average acre yield for this period was 16.9 bushels.

Corn is an important feed crop, both as grain and as forage (14). Observations indicate that it is a more reliable source of forage during dry years than other crops commonly grown for this purpose. According to United States Department of Agriculture Department Bulletin No. 1301 (19), observations and field trials at the United States Northern Great Plains Field Station, near Mandan, show that in this section corn usually produces enough ears to make it exceed any of the other silage crops in feeding value. On the average, corn is perhaps the best forage crop for either fodder or silage. During the years that corn has been grown at the station it has produced more pounds of grain to the acre than any of the small grains. It is the one crop that has not been a complete failure under some particular cultural treatment during the driest years. Corn grain is used principally as feed for hogs, cattle, and poultry, and the forage as either roughage or silage for cattle, sheep, and to some extent for horses. Most of it is fed from the shock, although some is husked; that from a small acreage is hogged off, and a few farmers use it for silage.

According to the Northern Great Plains Field Station, Falconer Semi-Dent, Northwestern Dent, and Minnesota 13 are the best varieties for grain. The Falconer Semi-Dent is the most common of all varieties grown. Rainbow Flint and Mercer are good fodder or silage varieties, and Gehu, because of its low growth, is desirable for hogging off.

Corn fills an important place in the crop rotations suitable for this area. It is displacing summer fallow to some extent as a successful means of preparing the ground for a good wheat or flax crop. Results at the Northern Great Plains Field Station show that summer fallow followed by wheat gave a total yield of 21 bushels of wheat for the 2 years, whereas corn followed by wheat gave a total yield for the 2 years of 25 bushels of corn plus 17 bushels of wheat. The annual yield during the 16-year period 1911-26 ranged from 12 to 36 bushels an acre and averaged 23.7 bushels; whereas during the 8-year period 1929-36 it ranged from 1.8 bushels in 1934 to 18.5 bushels in 1931 and averaged 13.6 bushels. Average yields of 12.5 and 23.2 bushels are reported for 1938 and 1939, respectively.

Hay occupies the largest acreage of all subsistence or feed crops and is second to wheat in acreage of all crops. According to census data, in 1939 the total acreage for all hay, exclusive of sorghums, was 66,216 acres, as compared with 76,989 acres in 1929. The acreages of indi-

vidual hay crops in 1939 are reported as follows: Alfalfa, 1,209 acres; clover alone, 886; timothy alone or mixed with clover, 175 acres; small-grain hay, 3,998 acres; other tame hay, 26,400 acres; and wild hay, 33,548 acres. It is seen that approximately 50 percent of the total acreage of hay was wild hay. The acreage of small-grain hay varies according to the probable yield of other tame-hay crops, the scarcity of carried-over feed, and the possibility of failure of the grain yield. As stated earlier, oats are considered the most desirable grain to sow for hay. Millet probably accounts in large part for the relatively large acreage of other tame hay.

Sweetclover is grown to a considerable extent on the bottom lands of the Missouri River, but only a very limited acreage is grown on the uplands. Most of that on the bottom lands has been sown on uncleared pasture land for the purpose of improving the grazing. A small acreage, however, is used for hay. This crop under normal moisture conditions is well recommended for either hay or pasture. Its growth persists farther into dry periods than does that of the grasses, and its feeding value approximates that of alfalfa, although it is not so palatable. Both white and yellow varieties are grown. The yellow is more prostrate but is preferred for grazing because of its fine stalk. The white variety is more upright but has coarser or more woody stems. Sweetclover is adapted to both pasture and hay production on all of the more productive upland and bottom land soils. One of the chief drawbacks to the wider use of this crop and also alfalfa on the soils of the uplands, especially during the recent dry years, is the difficulty of obtaining and maintaining good stands.

The acreage of alfalfa exceeds that of sweetclover and showed a marked increase from 1920 to 1930. It is confined, however, more largely to the river bottoms and local sites where the most favorable moisture and subsoil conditions are to be found. Under average conditions on the better soils of the uplands, sweetclover appears to be more reliable than alfalfa. Where moisture conditions are comparatively good, however, as when the water table can be reached by the deep roots or where irrigation is practiced, alfalfa generally proves to be the more desirable crop of the two. The Havre, Hall, and Arnegard soils are the most desirable for this crop.

Alfalfa is sown either with or without a nurse crop. It is generally recommended that it be sown without a nurse crop and on ground that has previously been fallowed or used for a cultivated crop. By so doing a greater portion of the soil moisture reserve is available to the young alfalfa plants.

Millet is a common annual crop grown for hay and is fed principally to cattle. Siberian millet is the most common variety grown. Proso, or hog millet, is grown as a grain feed for hogs. These crops produce well except under severe drought conditions.

Only limited acreages of Sudan grass and sorghums for forage are grown. The growing season of this locality is evidently a little too short for these crops, although to add diversification to the crops grown and variety to the roughage for livestock, a small acreage of sorghum appears to be quite justified. Red Amber is one of the most suitable varieties for this area. Some farmers are inclined not to grow these two crops because of the possibility of prussic acid poisoning that may be brought about by certain conditions of weather and growth.

Crested wheatgrass appears to be the most satisfactory of the perennial grasses for reestablishing permanent hay meadows. Results obtained at the Northern Great Plains Field Station and the substation at Dickinson, N. Dak., indicate that the yields are greater, the stand more permanent, and the seed more virile than for western wheatgrass, slender wheatgrass, and brome grass. It also has possibilities, according to these same authorities, as a pasture grass, particularly if it is used in conjunction with other pasture crops that produce feed during midsummer. Crested wheatgrass makes particularly early growth in the spring. According to United States Department of Agriculture Technical Bulletin 307 (23), because crested wheatgrass has the ability to start growth early in the spring and to grow late in the fall, it fills a pasture need that is not met by other plants that are available for cultivated pastures in this area. This crop is comparatively dormant during midsummer; consequently it is used to advantage in conjunction with either native pasture or sweetclover to furnish early spring and summer grazing and, when moisture conditions are favorable, fall grazing, with the other pasture furnishing grazing during midsummer.

Many garden or truck crops can be raised under normal moisture conditions if special care is given them and favorable soil sites are selected. Areas of Arnegard or Grail soils located where soil moisture is naturally conserved are frequently chosen for garden sites. The most common truck crops grown in this area are potatoes, cabbage, tomatoes, rutabagas, sweet corn, melons, cucumbers, beets, carrots, beans, and onions (9). Irish Cobbler and Early Ohio are the most satisfactory varieties of potatoes for this area. The census reports 668 acres of potatoes on 1,043 farms in 1939.

The use of commercial fertilizer is limited. According to the census, 10 farms reported a total expenditure of \$2,201, or an average of \$220.10 per farm, for fertilizer used in 1919, and 3 farms a total of \$465, or \$155 per farm, in 1929. Manure is utilized by the better farmers, but a great tonnage is disposed of as waste in gullies and along creek banks. When used, it is generally spread thinly on land to be used for a cultivated crop or wheat the following year.

According to the census, 43.6 percent of the farms expended \$132,266 for labor in 1939, as compared with 50.8 percent employing labor in 1929. Although in the past a fair part of this expenditure was made for outside labor during harvest seasons, a greater part has been spent for labor available locally during recent years. Owing to improvement in machinery, the increased use of combines, the tendency of farmers to have their threshing done by small locally owned separators, and light crops due to drought and rust, the demand for outside labor has diminished. During the average season labor is hired by the month for the growing season and by the day during the sowing and harvesting seasons. There is little demand for year-round laborers.

Between 1930 and 1940 there was a decrease in the number of farms from 1,851 to 1,755, which offset the increase from 1,851 to 1,960 farms between 1930 and 1934. Drought and changes in methods of power farming have resulted in the consolidation of small farms and those held by absentee owners, whereas it is probable that a small part of the increase in the early thirties was caused by people returning from industrial centers to farms during the depression.

The United States census for 1940 indicates that of the 1,755 farms in the county, 1,273 range in size from 260 to 1,000 acres. The distribution of the farms within this range is rather even. For example, 317 of them range in size from 380 to 499 acres, and 330 farms range from 700 to 999 acres. There are 223 farms of more than 1,000 acres and but 73 of less than 140 acres, whereas in 1935 these numbers were 193 and 106, respectively. The average size of farm reported by the census in 1940 was 630.4 acres, as compared with 607.5 acres in 1930.

According to the 1940 census, 89.4 percent of the total land area of Morton County was in farms. In 1939 there were 312,905 acres reported as harvested cropland, compared with 442,715 acres in 1929. The census reports also that in 1939 there were 24,352 acres of crop failure, 110,681 acres of idle or fallow cropland, 121,303 acres of plowable pasture, and 11,084 acres of woodland. All other land totaled 526,043 acres.

In the 1940 census 1,755 farms reported a value of \$12,559,097 for land and buildings, 1,681 farms reported a value of \$3,647,160 for buildings alone, and 1,657 farms reported a value of \$1,548,403 for implements and machinery. The average value per farm was \$7,156 for land and buildings, \$2,170 for buildings alone, and \$934 for implements and machinery. The average value for land and buildings per acre in 1940 was \$11.35, as compared with \$19.41 in 1930. The average value of livestock per farm was \$1,319.

The United States census data indicate a gradual increase in land tenancy. The percentage of farms operated by tenants in 1900 was 4.7; in 1910, 2.7; in 1920, 16.9; in 1930, 26.5; and in 1940, 37.4. In 1940 there were 523 full owners, 567 part owners, and 657 tenants. In that year renters operated 328,625 acres, as compared with 743,486 acres operated by owners and part owners. Share rental is the prevailing system under which farms are operated by tenants. A common practice is for the tenant to do all the work, furnish all seed, pay all financial expenses involved in producing the crop, and haul all produce to market. The owner pays the taxes. Under such an arrangement the renter receives three-fourths of the crop and the use of the farmstead. Frequently the owner assumes a greater part of the financial obligations, in which case he receives a larger part of the crop. When grazing land is rented, the rate is generally a stipulated cash payment per head, varying according to the length of time the livestock are grazed.

Farm equipment depreciated in value and in number during the drought years, but with improvement in moisture conditions new machinery, especially power machinery, has been increasingly evident. Under the more favorable crop conditions, most farms are equipped with machinery to seed, cultivate, and harvest their own crops. Combines are replacing threshing machines, which formerly were generally owned by cooperative groups or by individuals who made a business of doing such work. Few farms have extensive buildings, although shelter for a few work animals and a few cattle is generally provided, and nearly all farms have some storage room for grain. Most of the hay is stacked. Protection for farm implements is given by some of the farmers and ranchers, although a considerable part of this equipment stands in the open throughout the year. There are very few silos in the county except on a few dairy farms adjacent to Mandan and New Salem.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field and the recording of their characteristics, particularly in reference to the growth of various crops, grasses, and trees.

The soils and the underlying formations are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, cellars, and wells, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called collectively the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail, and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The content of lime in the soil profile is determined by simple tests. The drainage, both internal and external, and other external features, such as relief or lay of the land, are taken into consideration, and the interrelation of soil and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, with special emphasis upon the features that influence the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics the soils are grouped into classification units, the three principal ones of which are (1) series, (2) type, and (3) phase. In some places two or more of these principal units may be in such intimate or mixed pattern that they cannot be clearly shown separately on a small-scale map but must be mapped as (4) a complex. Some areas of land—such as Scoria and Rough broken land—that have no true soil are called (5) miscellaneous land types.

The series is a group of soils having the same developed layers, similar in their important characteristics and arrangement in the soil profile and formed from one type of parent material. Thus, the series comprises soils having essentially the same color, structure, natural drainage conditions, and other important internal characteristics and the same range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The series are given geographic names taken from localities near which the soils were first identified. Williams, Morton, Flasher, and Grail are names of important soil series in Morton County.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, or clay, is added to the series name to give the complete name of the soil type. For example, Morton loam and Morton clay loam are soil types within the Morton series. Except for the texture of the surface soil, these types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is generally the unit to which agronomic data are definitely related.

A phase of the soil type is a variation within the type, differing from the type in some minor feature, generally external, that may be of special practical significance. Differences in relief, stoniness, and degree of accelerated erosion are frequently shown as phases. For example, within the normal range of relief for a soil type certain areas

may be adapted to the use of machinery and the growth of cultivated plants and others may not. Even though no important differences may be apparent in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated plants. Under such conditions the more sloping parts of the soil type may be segregated on the map as a sloping or a hilly phase. Similarly, some soils having differences in stoniness, even though these differences are not reflected in the character of the soil or in the growth of native plants, may be differentiated as phases.

The term "arable land" refers to land that in its present condition is suitable without further substantial improvement for the production of crops requiring tillage. Texture refers to the relative amounts of clay, silt, and various grades of sand making up the soil mass. Light-textured soils contain much of the coarser separates (sands), and heavy-textured soils contain much clay. Structure refers to the natural arrangement of the soil material into aggregates or structural particles or masses. Consistence is a term that has come into rather recent use as regards soil characteristics and refers to such conditions as friability, plasticity, stickiness, hardness, compactness, toughness, and cementation. Permeability and perviousness connote the ease with which water, air, and roots penetrate the soil. Parent material is the unconsolidated mass from which the soil develops. The profile is a vertical section of the soil through all its layers and extending into the parent material. The solum is the upper part of the soil profile above the parent material in which the processes of soil formation are taking place. Tillable land under normal conditions can be devoted, with at least a fair measure of success, to crops requiring tillage of the soil. Where free calcium carbonate (commonly called lime) or other carbonate salts are comparatively abundant in the soil material, a bubbling or effervescence takes place when the soil mass is treated with an acid. Therefore, treatment of a sample of soil with an acid indicates whether or not free carbonates are present in abundance.

In a practical sense, the degree of acidity may be thought of as the degree of poverty in lime (available calcium), or as indicating the quantity of lime that should be applied for certain crops, such as some of the legumes. An alkaline soil in this county is rich in available calcium, and a neutral soil contains a sufficient quantity for any crop commonly grown. The term "reaction" ¹¹ refers to the condition of the soil as regards lime content or degree of acidity.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, complexes, and miscellaneous

¹¹ The reaction of the soil is its degree of acidity or alkalinity, expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality; higher values indicate alkalinity, and lower values acidity. Terms that refer to reaction and are commonly used in this report are defined in the Soil Survey Manual (7) as follows.

	pH value
Extremely acid.....	< 4.5
Very strongly acid.....	4.5-5.0
Strongly acid.....	5.1-5.5
Medium acid.....	5.6-6.0
Slightly acid.....	6.1-6.5
Neutral.....	6.6-7.3
Mildly alkaline.....	7.4-8.0
Strongly alkaline.....	8.1-9.0
Very strongly alkaline.....	> 9.1

land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS

With a few exceptions the soils of Morton County have developed in a semiarid climate under a cover of short grasses or mixed short and tall grasses. They exhibit, therefore, the characteristics of the Chestnut soils unless their development has been modified by local influences, such as steep relief, poor drainage, or other factors. The well-drained soils of the undulating to rolling uplands developed from the sandstones, shales, and clays of the Fort Union and Lance formations are representative Chestnut soils, and accordingly they are characterized by (1) a dark grayish-brown or dark-brown surface soil, (2) a well-defined prismatic structure to a depth of about 16 inches, and (3) a visible accumulation of carbonates at a depth of about 16 inches or more. Prismatic structure in these soils refers to that arrangement of the soil particles whereby the aggregates appear in place as elongated prisms ranging from 4 to 8 inches in length. The prisms are firm but on removal fall readily into smaller nutlike aggregates that are held together by grass roots. When broken horizontally their outline is subangular or irregularly rounded. The common range in diameter is from $\frac{1}{2}$ to $1\frac{1}{2}$ inches. The reaction is commonly neutral or slightly acid in the surface soils and alkaline in the subsoils. These soils are easily tilled, and they are inherently fertile. Lack of adequate moisture is the principal limitation to crop production.

Although most of the soils of this county tend to possess in some degree the characteristics listed above, a considerable range exists. Depending on the character of the parent material, the texture ranges from loamy fine sand to clay; and depending largely on the content of organic matter, the color ranges from very dark grayish brown to gray. The range in consistence—from loose loamy fine sand to intractable and massive clay—is extremely wide. The surface relief, or lay of the land, covers the entire range from flat depressions to steep hills or buttes. Other variations occur in respect to depth to carbonates, degree of influence of salts or "alkali," drainage, stoniness, and accelerated erosion.

Certain of these characteristics are commonly associated. For example, hilly relief, slight depth to carbonates, a comparatively light color of the surface soil, low content of organic matter, and good to excessive surface drainage feature many of the soils of the hilly sections of the county. In contrast, dark color of the surface soil, greater depth to carbonates, increased content of organic matter, and slow surface drainage characterize the soils of the smooth depressions. Lack of adequate surface drainage and seepage from the adjoining uplands may result, however, in the soils of the depressions being characterized by accumulations of salt and alkali. Other soils of the depressions or those at the foot of slopes may be composed of light-colored comparatively coarse sediments that have been recently deposited as raw alluvium from the local adjoining uplands. These examples illustrate some of the variable local situations that give rise to a considerable number of soils differing in their characteristics and consequently in their productivity.

The soils of Morton County are classified in 20 series, which include 34 types, 21 phases of types, 18 complexes of types, 8 complexes of phases, and 6 miscellaneous land types.

The Williams series includes the dark grayish-brown mature soils developed from olive-drab gravelly friable silty clay glacial till. The Morton series includes the dark grayish-brown soils developed from silty and clayey materials of the Fort Union and Lance geologic formations. The Bainville series includes the grayish-brown or light-brown soils developed from silty and clayey materials of the Fort Union and Lance geologic formations. The Searing series includes the reddish-brown soils developed for the most part from beds of scoria. The Flasher series includes the dark grayish-brown and grayish-brown to brown soils developed from sandy beds of the Fort Union, Lance, and Fox Hills geologic formations. In general, the Williams and Morton soils occur on the smooth to undulating uplands, whereas the Bainville, Searing, and Flasher soils occur on the more rolling and hilly uplands. A very well-defined prismatic structure characterizes both the Williams and Morton soils.

The Arnegard series includes the very dark to dark grayish-brown soils developed from local alluvium that has accumulated in the depressions and on some of the lower slopes, associated with the Williams and Morton soils. The Timmer series includes the very dark to dark grayish-brown soils developed from local alluvium that has accumulated in the depressions and on some of the lower slopes, associated with the Flasher soils. The material below the main body of Timmer soil is sandy, whereas that below the Arnegard is silty or clayey. The Grail series includes the very dark to dark grayish-brown soils developed from local alluvium that lies on gentle valley slopes immediately below the upland areas from which the alluvium was derived. The Patent series includes the brownish-gray soils developed from local alluvium that also lies on gentle valley slopes immediately below the upland areas. Both Grail and Patent soils are developed in most areas from silty and clayey local alluvium. There are, however, several areas of Patent loamy fine sand along the border of the Cannonball River valley in the vicinity of Breien, where the local alluvium is derived from sandy material of the adjoining uplands underlain by Fox Hills sandstone.

The McKenzie series includes the dark-gray to nearly black hard intractable alkali soils developed on clay alluvium of dry pond sites. The Dimmick series includes bare or semibare soils occupying abandoned stream channels and pond sites. The surface soil may have a small accumulation of organic matter below which is poorly drained mottled gray and yellow material.

The Hall series includes the very dark to dark grayish-brown friable mature soils developed from fine-textured materials of the terraces, alluvial fans, and natural levees underlain by either silty or clayey material. The Cheyenne series includes the dark grayish-brown to brown soils developed on the gravelly or sandy terraces or alluvial fans.

The Cherry series includes the brownish-gray soils that effervesce at or within a very few inches of the surface when treated with an acid and that are developed from the clayey alluvium of low stream benches or terraces. The Huff series includes dark grayish-brown to light-brown soils of the alluvial fans or terraces and sandy natural levees.

which generally effervesce within a few inches of the surface when treated with an acid. Clayey alluvium may lie at a depth of 3 to 4 feet or less.

The Havre series includes the grayish-brown to brownish-gray friable soils underlain by silty clay alluvium of the first bottoms along the rivers. These soils have an abundance of carbonates from the surface downward. The Banks series includes the grayish-brown to brownish-gray soils underlain by sandy alluvial material of the first bottoms along the rivers. These soils effervesce when treated with an acid at or within a very few inches of the surface.

The Moline, Rhoades, and Wade series are characterized by alkali claypans and are known as Solonetz soils. Areas of these soils are characterized by bare clay spots that have resulted from the removal (largely by wind erosion) of the surface soil above the claypan.

The Rhoades series includes the grayish-brown claypan soils developed on the uplands in association with the Williams and Morton soils. The Moline soils are brownish-gray to dark grayish-brown claypan soils developed in the gentle valley slopes of local alluvium and are associated with the Patent and Grail soils. The Wade series includes the very dark to dark grayish-brown claypan soils developed on the terraces, alluvial fans, and natural levees along the streams. A comparatively large acreage of the Wade soils are influenced by soluble salts. This variation is known technically as the Solonchak soils. Since the claypan (Solonetz) and Solonchak soils occur in very close association geographically, it was impracticable to differentiate the areas in mapping, and so the Solonchak soils have been included with the Solonetz soils. As these claypan and salty soils develop locally in spots from a few feet to several rods in diameter, individual areas cannot be shown on the soil map of the scale used. They are mapped as complexes with the associated soils and are named accordingly. Thus, Moline-Patent clay loams, Rhoades-Morton loams, Wade-Hall silty clay loams, and others appear on the map.

Where the claypan characteristics are less well developed, either in the proportion of the area affected or in the intensity of the development of the claypan, the soils are also shown as complexes; but in these instances the compound series name begins with the name of the member not possessing a claypan characteristic. Since the claypan is not so widely or intensely developed in these areas, it does not ordinarily prevent tillage. Thus, the Morton-Rhoades complex represents areas of Morton soils in which the claypan is moderately developed. Similarly, the Bainville-Rhoades complex, the Patent-Moline complex, and the Hall-Wade complex represent, respectively, areas of Bainville, Patent, and Hall soils in which the claypan is only moderately developed.

Alluvial soils, undifferentiated, comprise fresh alluvium of variable character along the smaller streams and drains. Rough broken land includes the rough, steep, partly bare hills and buttes composed of the sands, silts, and clays of the Fort Union, Lance, and Fox Hills formations; Scoria includes rough, steep, partly bare areas of Scoria; and Riverwash includes areas of loose bare sand adjacent to the larger stream channels.

Table 3 shows the principal characteristics of the soil series in Morton County.

TABLE 3.—Principal characteristics of soil series in Morton County,

Series	Position	Topography	Parent material	Dominant native vegetation	Color of surface soil
Arnegard...	Slight depressions in the uplands	Nearly flat.....	Medium-textured local alluvium	Mixed tall and short grasses	Very dark grayish brown
Bainville...	Gently rolling to steep uplands.	Undulating to steep	Silt and clays of Fort Union and Lance formations.	Short grasses	Grayish brown to brownish gray.
Banks ...	Bottom lands	Flat to undulating..	Sandy alluvium.....	Cottonwood, elm, and boxelder.	do.....
Cherry.....	Low terraces	Flat to gently sloping	Fine-textured alluvium	Short grasses, some sagebrush.	Brownish gray.....
Cheyenne...	Terraces	Flat to undulating, except for steep phase	Medium- or coarse-textured old alluvium	do.....	Dark grayish brown to brown.
Dimmick...	Sites of old stream channels, old ponds, or other depressions	Flat.....	Fine-textured alluvium.	Nearly bare, or hydrophytic types	Gray.....
Flasher....	Undulating to hilly uplands.	Undulating to steep	Sands of Fort Union, Lance, and Fox Hills formations.	Mixed tall and short grasses.	Dark grayish brown to brown.
Grail.....	Lower slopes	Gently sloping to sloping	Fine-textured local alluvium	do.....	Very dark to dark grayish brown.
Hall.....	Benches or terraces.	Flat to undulating..	Medium- to fine-textured old alluvium	do.....	do.....
Havre.....	Bottom lands	Nearly flat.....	Fine-textured general alluvium.	Cottonwood, elm, and ash	Grayish brown to brownish gray.
Huff.....	Natural levees, alluvial fans, and low terraces	Nearly flat to gently sloping	Coarse- or medium-textured alluvium.	Mixed grasses, some sagebrush.	Dark grayish brown to light brown.
McKenzie...	Sites of former ponds	Flat.....	Fine-textured lacustrine material	Annuals, wheatgrass..	Dark gray to nearly black.
Moline.....	Lower slopes	Gently sloping to sloping	Fine-textured local alluvium and colluvium.	Scattered short and tall grasses.	Grayish brown to brownish gray.
Morton....	Smooth to rolling uplands.	Undulating to rolling.	Silt and clays of Fort Union and Lance formations	Short grasses.....	Dark grayish brown.
Patent.....	Lower slopes.	Gently sloping to sloping.	Fine-textured local alluvium and colluvium.	Mixed short and tall grasses	Brownish gray.....

TABLE 3.—Principal characteristics of soil series in Morton County, N. Dak.

Series	Position	Topography	Parent material	Dominant native vegetation	Color of surface soil
Rhoades	Smooth to rolling uplands	Flat to rolling	Silt and clays of Fort Union and Lance formations	Scattered short and tall grasses	Grayish brown
Searing	Smooth to hilly uplands	Undulating to hilly	Mixed silts and clays of Fort Union formation and scoria	Mixed short and tall grasses	Dark reddish brown
Timmer	Slight depressions in the uplands	Nearly flat to gently sloping	Sandy local alluvium	Mixed tall and short grasses	Very dark to dark grayish brown
Wade	Bottom lands and terraces	Nearly flat	Fine-textured alluvium	Scattered mixed grasses, each, and other vegetation	do
Williams	Smooth to rolling uplands	Undulating to rolling	Medium- and fine-textured glacial till	Mixed tall and short grasses	Dark grayish brown

¹ As more recently defined, the Hall series is confined to Chernozems developed on loess-mantled terraces. County should be considered as a separate series.

The soils are classified in five slope classes, or groups, according to the lay of the land.

The first class includes soils of the nearly level areas, or those that do not have a slope in excess of about 2 percent. In other words, the elevation changes less than 2 feet for every 100 feet of horizontal distance. Areas having a surface of this character offer the minimum of difficulty to the operation of farm machinery and are least subject to erosion by runoff. Surface drainage, however, is slow and is somewhat detrimental on the heavier textured soils. This lay of the land is common to the soils of the Havre, Hall, Cherry, Huff, Wade, Arnegard, Timmer, and some of the Banks soils.

The second class includes soils of the undulating to gently rolling or gently sloping areas, ranging in slope from about 2 to 7 percent. Such areas offer very little difficulty to the operation of farm machinery, and they are not sufficiently sloping to be subject to any significant loss of soil by runoff water. Surface drainage is good, and the depth of the surface soil layers above the zone of carbonate accumulation is comparatively uniform within the individual areas. This range of slope predominates on the Williams, Morton, Grail, Patent, Moline, and Rhoades soils.

The third class includes soils of the rolling and sloping areas with a range in slope of about 7 to 15 percent. This class includes the various rolling and slope phases, such as Morton loam, rolling phase, and Patent clay loam, slope phase. So far as their slope is concerned, these soils are considered suitable for crops requiring tillage; but machinery, particularly heavy machinery, is handled with considerably greater difficulty than on the smoother areas. In general, surface drainage is excessive, especially on the steeper parts; the depth to carbonates is uneven in individual areas; and the more exposed areas are subject to both accelerated erosion and soil blowing if tilled.

The fourth class includes soils of the sharply rolling or hilly areas, which have a range in slope of about 15 to 30 percent. Such areas are considered too steep to be suitable for tillage. Farm machinery is operated with great difficulty, and the soils are generally droughty and markedly subject to erosion when tilled. Practically all areas are in their natural state and as such afford fairly good grazing. This class of soils includes the hilly phases of the various soil types.

The fifth class includes soils of the steeply sloping areas, having a slope greater than 30 percent. This class includes the steep phases of the various soil types, such as Bainville loam, steep phase. These areas are suitable only for grazing, but owing to the generally poorer site conditions for plant growth, they are less desirable for grazing, both as regards the quality and the quantity of grass available, than are the less steep slopes. All steep land of which more than 50 percent of the surface is bare is classified as Rough broken land.

It should be noted that the soils of each series are limited in their range of slope, and no one series has soil types within all slope classes. This limitation is based on the scientific fact that changes in soil morphology are associated with changes in slope, but the changes in morphology do not have a consistent relation to slope. Obviously, then, slope cannot rightfully be considered independently of other soil characteristics.

In the progress of the survey, observations and records were made of the relative abundance of surface stone. Certain soil types are stone-free or comparatively so, whereas others have a considerable range of stoniness. Stony areas are shown on the map by symbol wherever stoniness becomes an important consideration in management of the land.

Areas of claypan and clay spots that develop as a result of the adverse influence of sodium are not confined altogether to the Rhoades, Moline, Wade, and McKenzie soils and the several complexes. Isolated spots occur within areas of other soils. Accordingly, symbols are used on the map to indicate the smaller areas affected by claypan, or Solonetz, development in those soils that ordinarily do not have such conditions.

In a similar manner appropriate symbols are used to designate the local areas affected by relatively high salt concentrations.

The soil types, phases, complexes, and miscellaneous land types are placed in six major groups, largely on the basis of topographic position, in order to point out more directly the relations between the landscape and the soils, as follows: (1) Soils of the smooth and undulating uplands, (2) soils of the rolling uplands, (3) soils of the hilly, steep, and broken uplands, (4) soils of the depressions and lower (concave) slopes, (5) soils of the terraces, alluvial fans, and natural levees, and (6) soils of the bottom lands.

Each major group comprises several subgroups, arranged largely according to the color of the surface soils. In this way it is hoped that certain of the relations between soil series, types, phases, complexes, and miscellaneous land types may be clarified, together with their capabilities for use. These major groups, their subgroups, and the several types, phases, complexes, and miscellaneous land types are listed in the table of contents. In the following pages the soils of Morton County are described in detail, and their agricultural importance is discussed; their location and distribution is shown on the accompanying soil map; and their acreage and proportionate extent are given in table 4.

SOILS OF THE SMOOTH AND UNDULATING UPLANDS

The soils of the smooth and undulating uplands are widely scattered throughout Morton County. There are, however, no large or continuous undissected tablelands, unless exception is made of Custer and Bohemian Flats. The many relatively small areas occur on ridge crests, low divides, broad swells, and upper valley slopes and form a part of the complex pattern of soils that characterizes the county.

The greater ease with which farm machinery can be operated on areas of smooth relief has encouraged the use of soils of this group for dry farming, instead of the more rolling and hilly uplands. The relatively smooth surface has also favored the retention of rain water by the soil, reduced loss of water and surface soil by runoff, and provided suitable sites for the growth of native grasses. Consequently, all of these forces and factors operating together have resulted in the development of relatively deep dark grayish-brown soils of desirable prismatic structure that are more productive for small grains than

TABLE 4.—*Acreege and proportionate extent of the soils mapped in Morton County, N. Dak.*

Type of soil	Acres	Per- cent	Type of soil	Acres	Per- cent
Williams silt loam.....	13, 120	1 1	Patent clay loam, eroded phase.....	2, 624	0 2
Williams clay loam.....	4, 032	3	Patent clay.....	192	(¹)
Morton loam.....	81, 792	6 6	Patent loamy fine sand.....	3, 520	3
Morton clay loam.....	46, 976	3 8	Grail-Moline silty clay loams.....	50, 560	4 1
Bainville loam, smooth phase.....	24, 768	2 0	Grail-Moline silty clay loams, slope phases.....	2, 240	2
Bainville clay loam, smooth phase.....	19, 712	1 6	Grail-Moline silt loams.....	1, 856	2
Searing loam.....	1, 344	1	Patent-Moline clay loams.....	55, 296	4 5
Flasher fine sandy loam.....	43, 712	3 5	Patent-Moline clay loams, slope phases.....	6, 720	5
Flasher loamy fine sand, smooth phase.....	17, 024	1 4	Patent-Moline silt loams.....	3, 328	3
Morton-Rhoades loams.....	19, 904	1 6	Patent-Moline fine sandy loams.....	6, 208	5
Morton-Rhoades clay loams.....	20, 928	1 7	Moline-Grail silty clay loams.....	7, 360	6
Bainville-Rhoades loams.....	2, 304	2	Moline-Patent clay loams.....	32, 704	2 7
Bainville-Rhoades clay loams.....	12, 224	1 0	Moline-Patent clay loams, slope phases.....	3, 200	3
Rhoades-Morton clay loams.....	4, 288	3	Moline-Patent fine sandy loams.....	6, 016	5
Rhoades-Bainville clay loams.....	2, 304	2	McKenzie clay.....	3, 520	3
Morton loam, rolling phase.....	33, 472	2 7	Dumnick clay.....	448	(¹)
Morton clay loam, rolling phase.....	15, 424	1 2	Hall silt loam.....	18, 880	1 5
Bainville loam.....	67, 904	5 5	Hall loam.....	8, 704	7
Bainville clay loam.....	32, 256	2 6	Hall silty clay loam.....	7, 680	6
Searing loam, rolling phase.....	1, 344	1	Cheyenne loam.....	320	(¹)
Flasher fine sandy loam, rolling phase.....	26, 368	2 1	Cheyenne fine sandy loam.....	10, 688	9
Flasher loamy fine sand.....	32, 320	2 6	Cheyenne gravelly loam, steep phase.....	1, 024	1
Morton-Rhoades clay loams, roll- ing phases.....	8, 832	7	Cherry clay.....	1, 344	1
Bainville-Rhoades loams, rolling phases.....	1, 920	2	Huff silt loam.....	3, 072	2
Bainville-Rhoades clay loams, roll- ing phases.....	6, 336	5	Huff very fine sandy loam.....	5, 376	4
Rhoades-Morton clay loams, roll- ing phases.....	448	(¹)	Huff loamy fine sand.....	1, 280	1
Rhoades-Bainville clay loams, roll- ing phases.....	2, 048	2	Hall-Wade silty clay loams.....	18, 816	1 5
Bainville loam, hilly phase.....	76, 032	6 2	Hall-Wade silt loams.....	7, 936	6
Bainville loam, steep phase.....	31, 488	2 6	Wade-Hall silty clay loams.....	16, 448	1 3
Bainville clay loam, hilly phase.....	40, 512	3 3	Havre silty clay.....	3, 264	3
Bainville clay loam, steep phase.....	12, 672	1 0	Havre silty clay, poorly drained phase.....	1, 792	1
Flasher loamy fine sand, hilly phase.....	48, 960	4 0	Havre silt loam.....	1, 856	2
Flasher loamy fine sand, steep phase.....	22, 656	1 8	Havre fine sandy loam.....	1, 088	1
Searing loam, hilly phase.....	2, 752	2	Banks very fine sandy loam.....	4, 672	4
Rough broken land.....	4, 992	4	Banks loamy fine sand.....	8, 768	7
Scoria.....	4, 608	4	Banks silty clay.....	2, 112	2
Arnegard silt loam.....	7, 552	6	Banks silty clay, poorly drained phase.....	576	(¹)
Timmer loam.....	1, 728	1	Alluvial sandy soils, undifferen- tiated.....	2, 944	2
Timmer fine sandy loam.....	2, 048	2	Alluvial loam soils, undifferen- tiated.....	23, 296	1 9
Grail silty clay loam.....	49, 344	4 0	Alluvial clay soils, undifferen- tiated.....	6, 464	5
Grail silt loam.....	26, 432	2 1	Riverwash.....	832	1
Grail silty clay loam, slope phase.....	2, 880	2			
Grail silt loam, slope phase.....	1, 984	2			
Patent clay loam.....	6, 720	5			
Patent clay loam, slope phase.....	2, 432	2			
			Total.....	1, 237, 120	100 0

¹ Less than 0.1 percent

are the soils of the hilly and steep uplands, and for these reasons the smooth and undulating uplands together with the terraces and bottoms are used most intensively for crops.

Because of differences in the texture and color of the various parent materials (glacial till, shales, clays, sands) and in conditions of drainage, not all of the soils, even in the smooth uplands, are alike. In fact, the grouping of soils on the basis of slope and topographic position places many otherwise dissimilar soils together. Textures range from fine sands to clay loams. The color of the surface soils varies from dark grayish brown to reddish brown. Some of the soils are comparatively porous and droughty; others are compact and relatively impervious. These differences form the basis of the subgroups.

DARK GRAYISH-BROWN SOILS

The dark grayish-brown soils of the smooth and undulating uplands are so designated because of the dark grayish-brown color that extends to a depth of about 16 inches and indicates a relatively high content of organic matter. These soils are well drained, have a pronounced prismatic structure, are friable and easily worked, and are free from abundant carbonates in the upper 16 inches.¹² Williams silt loam, Williams clay loam, Morton loam, and Morton clay loam compose the soils of this subgroup. The natural fertility, good tilth, good water-holding capacity, and smooth surface of these soils make them well adapted to wheat and the other small grains, corn, and hay—crops that are commonly grown. Soil blowing is not a serious problem. The clay loams are slightly less desirable than the loams because of the heavier textures and less satisfactory moisture relations.

Williams silt loam.—This soil is developed from glacial till and for the most part occupies comparatively broad smooth to gently rounded ridge tops. The surface is undulating to gently rolling. Surface drainage is good, and internal drainage is sufficient to maintain good moisture conditions for plant growth.

The parent material of Williams silt loam is olive-drab friable gravelly clay till, which extends to a depth of 3 to 10 feet. This material is underlain by the Fort Union or Lance formations. In some places, however, because of the uneven and irregular occurrence of the till, there are small included areas in which the till is very thin or missing altogether.

The native vegetation is mixed tall and short grasses. Blue grama is the dominant grass, with some western wheatgrass, needlegrass, and porcupine grass. The most common shrubs and herbs are pasture sagebrush, green sagebrush, and Indian turnip; and some clubmoss is common to most virgin areas. Pasture sagebrush occurs where overgrazing has been practiced. Prairie plantain is a very common plant and dominates the native vegetation, particularly in moist spring seasons following a previous dry fall. On areas where overgrazing has been practiced such weeds as wild onions and lambsquarters are common.

The aggregate area of Williams silt loam is 20.5 square miles. It occurs in the northeastern and eastern parts of the county. The greatest acreage is in T. 138 N., Rs. 81 and 82 W.

Williams silt loam has the following profile characteristics:

0 to 6 inches, dark grayish-brown to very dark grayish-brown friable silt loam.

Reaction is very slightly acid to neutral.

6 to 15 inches, dark grayish-brown heavy silt loam with pronounced prismatic structure. When removed from place with a spade the mass breaks into nearly regular blocky nut-sized fragments that are easily crushed to a mealy mass. The reaction is very slightly acid to neutral.

15 to 20 inches, transitional to friable olive-brown silty clay loam with prominent prismatic structure. Sufficient carbonates are present for the soil to effervesce when treated with acid.

20 to 30 inches, friable olive-drab silty clay with numerous whitish carbonate flecks distributed through it. Prismatic structure extends into this layer but becomes indistinct with depth. Some gravel and an occasional boulder are distributed through the soil material.

¹² The term "abundant carbonates" is used here to indicate the presence of sufficient carbonates to cause effervescence when a sample of the soil is treated with a dilute acid solution. Generally, although not everywhere in the county, the most productive soils are free of abundant carbonates to a depth of 10 to 12 inches.

30 inches +, friable olive-drab silty clay that comes from place as easily crushed irregular chunks. There are numerous whitish carbonate flecks, but the greatest concentration of them is in the material from a depth of 20 to 30 inches.

Numerous small gravelstones are distributed throughout the soil, but they are not abundant enough to have any depreciating effect. Boulders in variable numbers lie on the surface and in the soil. Where they are plentiful enough to interfere with tillage operations they have been indicated on the map by symbol. Alkali or salty conditions are seldom found in this soil.

Some areas of Williams silt loam lying on Custer Flats (pl. 1, A and B), south of Mandan (T. 138 N., R. 81 W.) have a deeper and darker (very dark grayish-brown) surface soil than is representative of the typical soil. An area of approximately 500 acres in the vicinity of sec. 22, T. 138 N., R. 82 W., has a greater quantity of sand at a depth of 12 to 30 inches. The texture is loam rather than silt loam, and the prismatic structure is less well defined. The fragments that are broken out in place crush more easily to a crumbly mass than those of the typical soil. Olive-drab silty clay till underlies this material. The overlying loam appears to be wind-blown material and does not show any marked effervescence.

Williams silt loam is devoted largely to crops. Probably over 90 percent of it is tilled (pl. 1). Wheat is grown on more than 60 percent of the total acreage, and oats, barley, corn, and hay on most of the remaining tilled acreage. Hay crops, including part of the small grains cut for hay, occupy from 5 to 10 percent of the total acreage. This soil is one of the most productive of the uplands. Wheat yields from 14 to 17 bushels an acre, oats 30 to 35 bushels, barley 20 to 25 bushels, and flax 9 to 12 bushels, in average good years.¹³ Corn under favorable conditions yields from 25 to 30 bushels an acre for the grain varieties and from 2 to 3 tons for the forage varieties. Other crops well adapted but grown on a smaller scale are emmer, proso millet (for grain), crested wheatgrass, brome grass, sorghums (forage), alfalfa, sweetclover, millet, and potatoes.

Compared with other soils of the county, Williams silt loam has a high carrying capacity as range land and produces a grazing vegetation of good quality. Grazing experiments were conducted at the Northern Great Plains Field Station from 1915 to 1924, inclusive (16). On an area composed of Williams silt loam that included smaller areas of Arnegard silt loam, a 70-acre pasture, grazed by 2-year-old steers at the rate of 7 acres per head, provided approximately the area of land required to produce over a period of 5 months the maximum gain per head under a system of continuous grazing. Where a system of deferred and rotation grazing was used an area of 4 to 5 acres gave what appeared to be the most profitable returns over a 5-month grazing period. This acreage probably does not represent the carrying capacity of typical Williams silt loam, however, for the carrying capacity of Arnegard silt loam is somewhat greater than that of Williams silt loam. Allowing for the difference caused by the included acreage of Arnegard silt loam, the average carrying capacity

¹³ By yield in average good years is meant the approximate average yields for years that farmers consider to be better than failures. It is extremely difficult to obtain average yields for separate soil types because of the large range in yields from year to year, because of crop failures, and because of the intricate detail and variation in soils within individual fields. Hence the use of this general term of yield in average good years.

of Williams silt loam for a 5-month period of continuous grazing is probably about 8 acres per head.

Williams clay loam.—This soil is similar to Williams silt loam except that the texture of the surface layer is clay loam rather than silt loam. The total acreage is small, and none of the separate areas are extensive. Most of them are associated with areas of Williams silt loam. The surface is smooth, and the drainage is good. Practically all of it is tilled, is used for the same crops, and is handled much like the silt loam soil, except that the clay loam soil is more difficult to handle and is somewhat more restricted in its uses. Yields of staple crops and its grazing capacity are about the same as on the silt loam soil.

Morton loam.—This soil is the dark grayish-brown loam of the uplands that has been developed from the silts and clays of the underlying Fort Union and Lance formations. The surface is undulating to gently rolling, and the soil lies on smooth ridge tops or low hills, although a few areas are on gentle slopes. Surface drainage and internal drainage are good.

Morton loam is widely distributed throughout the county. The principal acreage is in the vicinity of Saint Anthony and to the south and southwest between Saint Anthony and Flasher. The total area is 127.8 square miles.

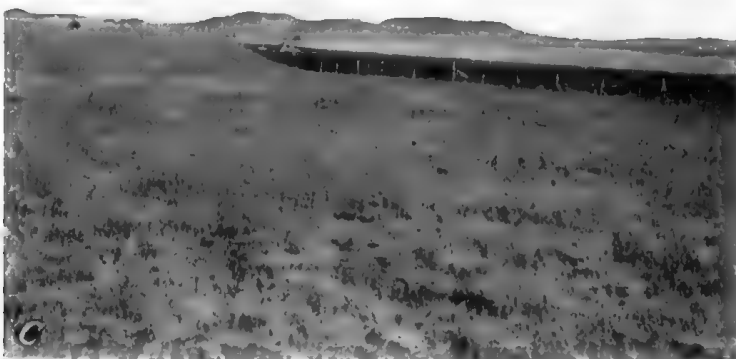
The native vegetation is chiefly blue grama grass intermixed with western needlegrass and western wheatgrass. Niggerwood displaces western wheatgrass on the sandier areas. Prairie junegrass and green porcupine grass are common but seldom abundant. Pasture sagebrush, clubmoss, and plantain are common on practically all virgin areas, and some green sages occur in places. In general, the natural vegetation is of a desirable type for grazing and the carrying capacity of the virgin grassland areas is high (pl. 1, C).

Although the parent material of Morton loam is the residual material that has weathered from the Fort Union and Lance formations, boulders are common to the soil. They are the only significant evidence of glaciation, since till was not evident in the areas mapped as Morton soils. The covering of glacial material over the areas of Morton soils in the county must have been thin, and except for the remaining boulders the original drift material has been removed by the processes of natural erosion.

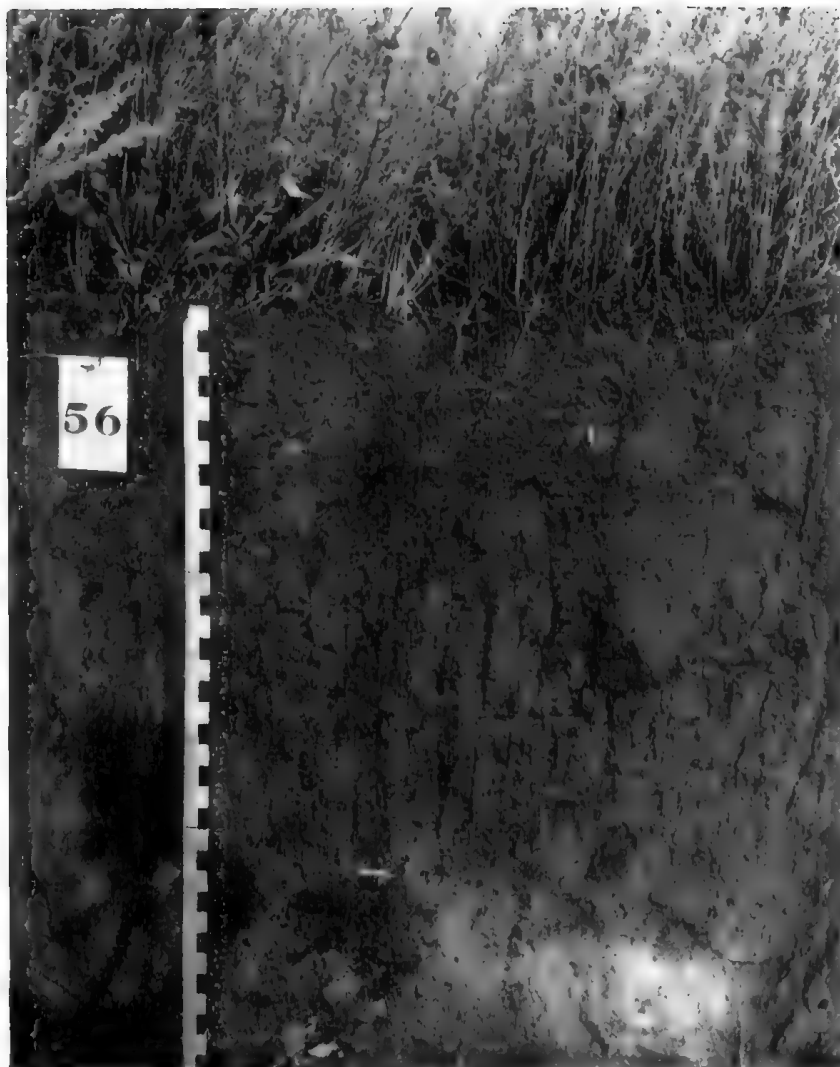
Morton loam (pl. 2) has the following profile characteristics:

- 0 to 4 inches, dark grayish-brown to very dark grayish-brown mellow loam with crumb structure. Slightly acid.
- 4 to 15 inches, dark grayish-brown silt loam with a well-developed prismatic structure that crushes easily to a crumbly mass. Very slightly acid to neutral.
- 15 to 18 inches, transitional layer of olive-brown loam to silt loam. Prismatic structure becomes less distinct, and flecks of carbonates appear.
- 18 to 25 inches, olive-gray to olive-drab friable silty clay; moderately alkaline; whitish carbonate flecks throughout.
- 25 inches +, olive-drab or olive-yellow sandy clay material with yellowish silty or clay laminations. The underlying material is variable from place to place.

A few areas are underlain by a thin bed of hard angular shale fragments more or less intermixed with silt and clay material. Some of the areas underlain by olive-yellow sandy clay have numerous very



A, Wheat and summer fallow on Williams silt loam on Custer Flats. Favorable topography, good tilth, and high fertility make the Williams soils highly productive for spring wheat in seasons of ample rainfall. **B**, Strip cropping with summer fallow. Grail silty clay loam occupies the ravine, or small draw, and Williams silt loam occurs on the higher lying areas. **C**, Blue grama is the principal grass on this pasture of Morton loam. Grail silty clay loam occurs on the lower part of the slope of the cultivated field on the right, and the hills in the background are principally the hilly and steep phases of Flasher loamy fine sand.



A profile of Morton loam. The prismatic structure of the B horizon and the underlying layer of accumulated calcium carbonate may be observed.



A, Farmstead with characteristic buildings on Morton loam. **B**, A farmstead in the sandy area bordering the Cannonball River valley. Cheyenne fine sandy loam in the foreground; Flasher loamy fine sand, hilly phase, occupies the slopes along the drainageway; and Moline-Patent fine sandy loams complex is on the upland above the haystack or hayrick on the right.

dark-brown ferruginous or sandstone fragments $\frac{1}{2}$ to 1 inch in diameter distributed through the soil. Areas north of Glen Ullin and in the vicinity of New Salem to the north for the most part are underlain by clay beds, and the depth of the grayish-brown layer in some places is less than the average indicated in the above description. Areas in the vicinities of Flasher, Fallon, and Timmer for the most part are underlain by sandy clay or sandy loam material. The depth to effervescence in the soils underlain by the heavier materials ranges from 17 to 24 inches in the sandier material. The surface layer of Morton loam in the eastern part of the county is slightly darker and from 2 to 3 inches deeper than in the rest of the county. Other variations include the shallow areas, usually on low knobs, where the grayish-brown surface layer extends to 1 foot or less. Such areas are very patchy in their occurrence and too small in extent to show separately on the soil map. These areas, where indicated by symbol on the field sheets, were given a lower rating in the land classification work for the county. Occasional areas of Morton loam, as mapped, have spots of claypan, and where these areas are too small to be shown on the map as areas of Morton-Rhoades soils the claypan condition is shown by appropriate symbol.

As previously mentioned, some areas of Morton loam have glacial boulders strewn over them. Where the stones are plentiful enough to hinder tillage their occurrence is indicated on the soil map by stone symbols. There are a few areas that have angular pieces of hard shale strewn over the surface instead of glacial boulders. These shale pieces range from 6 inches to $2\frac{1}{2}$ feet in diameter, and where they are plentiful enough to interfere with tillage their occurrence is shown by a stone symbol on the soil map. These rocks are most common in the vicinities of T. 135 N., R. 81 W., and to the northwest of New Salem.

Most of Morton loam is used for crops. Wheat, the most important crop, occupies about 60 percent of the total acreage. Oats, barley, corn, flax, and hay crops are grown on the remaining acreage. Because of its intermediate texture, this soil is well suited to intertilled crops and is easily handled, but it is not coarse enough to be subject to severe wind erosion. A representative farmstead is shown in plate 3, A. Some of the sandier areas that have been tilled with a moldboard plow for many years have developed a plow sole, which is a semicemented or compacted layer about $2\frac{1}{2}$ inches thick immediately below the plow layer. This layer is a hindrance to good root development and undoubtedly interferes somewhat with the movement of soil moisture. The plow sole can be broken up by the use of a subsoiling implement, but this practice is not common.

Morton loam is a productive soil, but the yields are more variable from year to year than those on Williams silt loam. In average good years wheat yields 12 to 16 bushels, oats 25 to 35 bushels, corn 20 to 30 bushels, and flax 8 to 12 bushels to the acre. The forage varieties of corn for similar years produce 2 to 4 tons an acre. In exceptionally good years oats yield 40 bushels, barley 30 bushels, and corn 40 bushels. The carrying capacity of virgin areas of range land of this soil is from 90 to 100 percent of that of Williams silt loam. As compared with Morton loam, the result of the grazing experiment carried out on Williams silt loam and Arnegard silt loam by the Northern

Great Plains Field Station (16) indicates that probably $8\frac{1}{2}$ acres are required to graze satisfactorily a 2-year-old steer for 5 months.

Morton clay loam.—This soil is similar to Morton loam, except that the texture of the surface layer is clay loam. It occupies undulating to gently rolling ridges and is widely distributed over the county. The aggregate area is 73.4 square miles. The areas are more scattered than those of Morton loam, and most of them are comparatively small. This soil occurs principally in the area extending southwest from Saint Anthony to north of Flasher and south and east of the Heart River. A fairly large acreage lies north and northwest of New Salem. The native vegetation is principally blue grama grass with some western wheatgrass and needlegrass intermixed.

Morton clay loam has the following characteristics:

- 0 to 4 inches, dark grayish-brown friable clay loam of crumb structure.
- 4 to 15 inches, dark grayish-brown clay loam with distinct prismatic structure. When dug from place, the prisms break into angular nut-sized fragments that crush readily under moderate pressure to a crumb structure.
- 15 to 20 inches, olive-brown or olive-yellow friable clay loam with prismatic structure that becomes ill defined with increasing depth. This layer contains flecks of calcium carbonate that effervesce when treated with acid.
- 20 inches +, olive-gray or olive-drab silty clay with ill-defined prismatic structure. The material comes from place as moderately hard angular fragments.

Variations exist in the depth of the dark grayish-brown soil over the layer of carbonate accumulation, and they are usually associated with variations in relief. The shallower soils are more common on the more pronounced crests and ridges.

Some of the areas of this soil have glacial boulders strewn over the surface, and a few have hard angular shale rocks on the surface. Where the boulders or the shale fragments are in sufficient number to interfere with tillage their presence is indicated on the soil map by stone symbols.

From 85 to 90 percent of Morton clay loam is tilled. Wheat occupies more than 50 percent of the total acreage. Barley, oats, flax, corn, and hay are the other important crops. Its heavier texture and consistence make this soil slightly more difficult to till than Morton loam. Yields of crops and the carrying capacity as grazing land are approximately the same as for Morton loam.

GRAYISH-BROWN SOILS

The grayish-brown soils of the smooth and undulating uplands differ essentially from the dark grayish-brown soils in having (1) a thinner and slightly less dark surface soil layer, (2) a slighter depth to carbonate, (3) a less well-defined prismatic structure, and (4) a generally more undulating relief, although the range in slope for the two subgroups is the same.

These characteristics make the Bainville soils less fertile and less productive than the Williams and Morton soils. Their water-holding capacity also is lower, their tilth is less uniformly good, they are more subject to soil blowing, and they are not so well suited to as many crops. There is, however, no great difference in the system of farming on these soils and that practiced on the Williams and Morton soils, although farmers recognize the smaller degree of success with which they are farmed and the lowered productivity over a period of years.

Bainville loam, smooth phase.—This soil occupies gently rounded ridge crests and knobs in the uplands. Both surface drainage and internal drainage are good to slightly excessive. The underlying parent materials are the silt and clay beds of the Fort Union and Lance formations.

The native vegetation consists of blue grama, niggerwool, needlegrass, and little bluestem. The grass cover is not so uniform or dense as on the Williams and Morton soils, and some weed growth is common even on the virgin areas. The land is considered, however, to be fairly good grazing land.

This phase has a total area of 38.7 square miles. Most of the areas are north of Glen Ullin, north of New Salem and Judson, and south and southwest of Almont. The individual tracts are small and irregular, and only a few are larger than 40 or 50 acres.

Bainville loam, smooth phase, has the following profile characteristics:

- 0 to 5 inches, grayish-brown to dark grayish-brown friable mellow loam. The soil comes from place as irregular lumps that are easily crushed. The 2- to 3-inch surface layer is slightly darker than the rest of the soil.
- 5 to 8 inches, light grayish-brown loam with indistinct prismatic structure. The structure becomes less distinct and the color more gray with depth.
- 8 to 12 inches, brownish-gray to olive-gray loam to clay loam. Carbonates are sufficient to produce effervescence when treated with acid.
- 12 inches +, gray and yellow laminated silts and clays, with an abundance of carbonates.

Boulders are on the surface of those areas in the northeastern part of the county where the evidence of glaciation is the greatest. Hard dense shale rocks are on the surface in other parts of the county. Where these boulders and shale rocks interfere with tillage they are indicated on the soil map by stone symbols.

Variations in the depth of the surface layer and in the depth to the layer of calcium carbonate accumulation are commonly associated with variations in the relief. Calcium carbonate occurs at the surface on some of the more exposed knolls.

Over 50 percent of the total area of Bainville loam, smooth phase, is tilled. Wheat is the most important crop, but corn and hay are commonly grown. In average good years wheat yields 10 to 12 bushels and millet about 1 ton to the acre. The general productivity for crop plants is estimated to be about 55 percent of that of Morton loam. As grazing land, virgin areas have a carrying capacity equal to about 80 percent of that of Morton loam.

The productivity is naturally somewhat low because of the rather droughty nature and relatively low content of organic matter. The fertility is more rapidly diminished with continuous cropping than in such soils as Williams silt loam and Morton loam. The small quantity of organic matter is largely responsible for the ease with which the soil crumbles to a fine-grained or floury mass, and when worked to this condition by tillage the soil is markedly subject to blowing; consequently special care is required to reduce the hazard of soil blowing.

Bainville clay loam, smooth phase.—This soil is comparable with Bainville loam, smooth phase, except that the texture is clay loam. It occupies rounded ridge tops, and in places is bordered by rolling to steeply sloping land. Most of the areas are in the western part of the

county, although isolated small tracts are distributed over most of the county north of the Heart River. Both surface drainage and internal drainage are good. The parent rocks are the clays and silts of the Fort Union and Lance formations, but the heavier texture of this soil as compared with Bainville loam, smooth phase, indicates a greater influence of the clay materials in its development.

The native vegetation is predominantly blue grama. In places niggerwool and little bluestem are abundant. Generally the grass cover is good, although there are many areas where it is uneven and even sparse. Weeds are common.

Bainville clay loam, smooth phase, has the following profile characteristics:

- 0 to 4 or 8 inches, dark grayish-brown to grayish-brown friable clay loam. This layer in some areas approaches a very dark grayish-brown color.
- 4 or 8 to 10 or 14 inches, grayish-brown clay loam with fair to indistinct prismatic structure. The prisms crush rather easily under pressure. White flecks of calcium carbonate are numerous, particularly in the lower part of the layer. Effervescence takes place commonly throughout the layer.
- 10 or 14 to 18 or 22 inches, olive-gray silt loam to silty clay with no evidence of prismatic structure. The texture and structure of this layer vary. Where silt predominates, the material generally comes from place as soft fragments or lumps. Where clay predominates, it comes from place as fairly hard irregular pieces.
- 18 or 22 inches +, below this depth the material lies as undisturbed geologic laminations that generally come from place as firm, angular, flattened fragments. Generally some of the laminations are yellow, and in places there are layers of shale broken to small pieces.

The above description indicates the general range in the variations of color, depth, structure, and texture of the layers common to this soil.

Boulders or shale rocks occur in some places, and where they are in sufficient number to interfere seriously with tillage, stone symbols have been placed on the soil map.

Probably 65 percent of Bainville clay loam, smooth phase, is tilled. About the same crops are grown and about the same yields are obtained as on Bainville loam, smooth phase, and the carrying capacity for grazing is also about the same. The heavier texture makes this soil less subject to blowing; but it also has a low content of organic matter, a low supply of available water, and an inability to maintain crop productivity under continuous cropping. The heavier texture makes it necessary for the farmer to exercise more care in its management, makes the soil more difficult to till, and is partly responsible for the low supply of available moisture for growing plants.

REDDISH-BROWN SOILS

The reddish-brown soils of the smooth and undulating uplands differ from the soils of the two preceding subgroups principally in the color of the soil layers and in the underlying scoria beds, which consist of red hardened shales together with irregular masses of red and black clinkers. The scoria beds have probably been formed by the burning of the lignite beds associated with the Fort Union formation prior to the advent of white men. Searing loam is the only soil included in this subgroup.

Searing loam.—This soil is underlain by beds of scoria. It occupies strongly undulating to gently rolling ridge tops. Both surface drain-

age and internal drainage are good. The individual areas are small and are generally associated with outcrops of scoria. The total area of this soil is 2.1 square miles. It occurs in the western part of the county, and most of it lies between New Salem and Glen Ullin.

The parent material is largely scoria fragments, although associated beds of silt and clay have contributed to the development of the soil. The native vegetation is predominantly blue grama with considerable niggerwool and needlegrass.

Searing loam has the following profile characteristics:

- 0 to 7 inches, dark reddish to very dark reddish or chocolate-brown loam with ill-defined prismatic structure. The indefinite aggregates crumble easily into soft fragments. Very small fragments of light-red scoria are generally distributed throughout this layer.
- 7 to 18 or 20 inches, reddish-brown to light reddish-brown loam to clay loam with indistinct structure. The material comes from place as comparatively soft chunks. Small fragments of scoria are numerous.
- 18 or 20 to 25 or 30 inches, the brown loam grades to a less friable parent material of variable character. In some places the material is mostly scoria; in others black lignitic material is encountered; and in others a mixture of scoria, shale, and olive-gray clay beds occurs. Effervescence generally does not occur within a depth of 25 inches.

Considerable variation exists in the depth of the underlying bed of scoria fragments, in the distinctness of the prismatic structure, in the texture of the underlying layers of soil and parent materials, and in the quantity of scoria present in the soil layers. Small patches of outcrops of scoria are rather common, and where they interfere with crop growth and tillage, the symbol for rock outcrop has been placed on the soil map.

There are a few small areas in which an alkali claypan is developed. Such areas have a somewhat lighter chocolate-brown surface layer with an underlying parent material that is almost invariably olive-gray clay and is relatively free of scoria fragments. These small areas, which are for the most part unsuited for tillage, are shown on the soil map by the claypan, or Solonetz, symbol.

Probably 70 percent of the total acreage of Searing loam is tilled. Small grains, particularly wheat, occupy the greater part of the tilled acreage. Corn grows comparatively well on this soil. Yields of the other commonly grown crops nearly equal those obtained on Morton loam, and the carrying capacity for grazing is estimated to be about 90 percent of that of Morton loam. The soil is friable, easily worked, and generally suited for growing farm crops, except that it commonly occurs in small areas that may contain patches or knobs with outcrops of scoria fragments.

DARK GRAYISH-BROWN TO BROWN SANDY SOILS

The dark grayish-brown to brown sandy soils of the smooth and undulating uplands are members of the Flasher series. The two soils of this subgroup—Flasher fine sandy loam and Flasher loamy fine sand, smooth phase—vary somewhat from each other in depth, color, and texture of the surface layers and in relief. These soils are sandy and therefore are easily tilled, droughty, and subject to blowing when cultivated. They are better suited to deep-rooted crops, such as corn, than to the shallow-rooted small-grain crops. The sandy porous surface layers of these soils, however, allow crops to make more efficient use of the moisture from light summer showers than do the finer

textured surface layers of the soils of the preceding three subgroups; consequently, during some seasons some crops do better on these soils than on the loams, silt loams, and clay loams. Flasher fine sandy loam is a more productive and desirable soil than Flasher loamy fine sand, smooth phase.

Flasher fine sandy loam.—This soil overlies the sandstones of the Lance and Fort Union formations. The areas are generally undulating to gently rolling and are situated either on the smoother ridge crests or on the lower lying upland tracts that are bordered by higher lying buttes, hills, or ridges. Both surface drainage and internal drainage are good.

The most extensive areas are in the vicinity of and to the northeast of Flasher. Other smaller areas are distributed over most of the county. The total area is 68.3 square miles.

The native vegetation varies from place to place according to the soil variations that have been permitted in the mapping of the soil. The finer textured areas and small depressions that have a surface relief favoring the accumulation or preservation of surface water have a mixture of blue grama, needlegrass, and other associated grasses. The representative areas of Flasher fine sandy loam and those that are inclined to be more sandy than average have a cover of about one-half blue grama and one-half niggerwool. Blue grama is the dominant grass of the areas with claypan development. Some of the scabby spots of the claypan areas are well grassed with blue grama; others are nearly bare or are occupied by weeds.

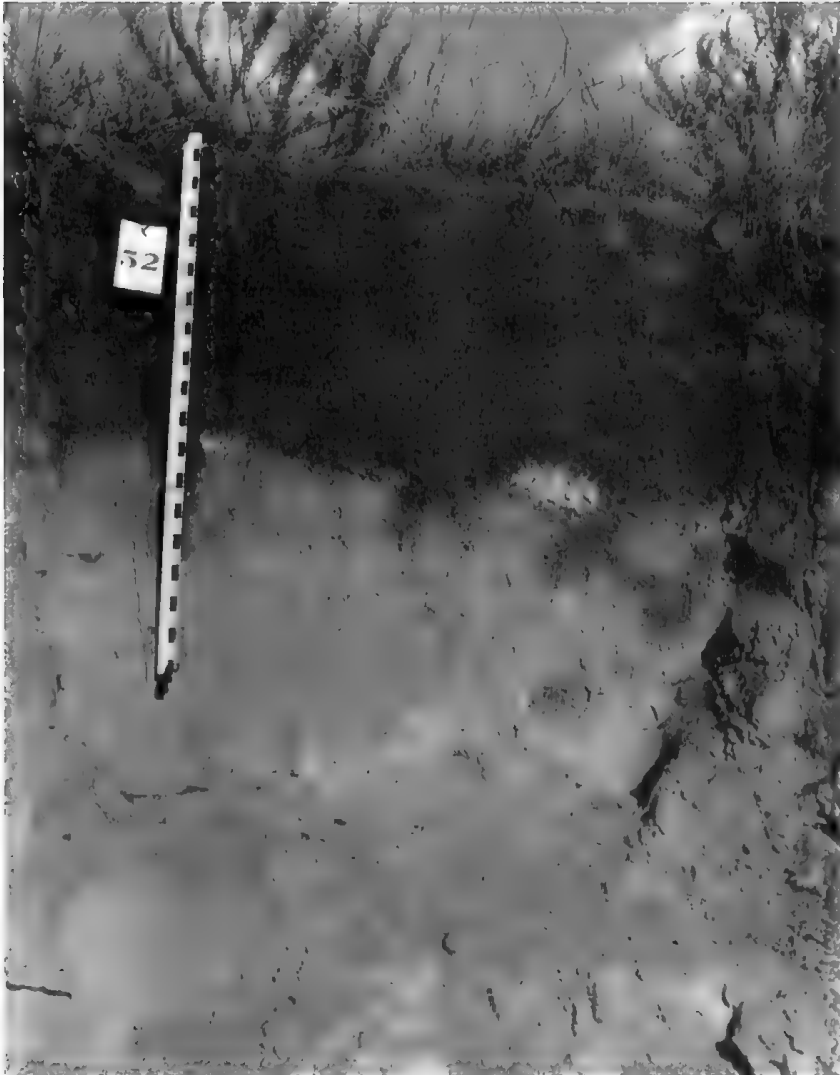
Flasher fine sandy loam has the following profile characteristics:

- 0 to 8 or 9 inches, dark grayish-brown or dark-brown fine sandy loam with coarsely prismatic structure. The soil, when dug from place, comes as fairly brittle irregular prisms and chunks. Areas that have been plowed with a moldboard plow for several years almost invariably have a hard brittle layer, or plow sole, about 3 inches thick that begins at a depth of about 5 inches.
- 8 or 9 to 18 or 21 inches, the color grades from dark grayish brown or dark brown to olive brown, and the texture becomes coarser. Structural units become less well-defined.
- 18 or 21 to 28 or 31 inches, olive-brown loamy fine sand that comes from place as irregular chunks that crush easily with a little pressure into single grains or small aggregates.
- 28 or 31 to 60 inches +, olive-yellow or olive-drab loose fine sand

The depth at which effervescence with an acid takes place ranges from 28 to more than 60 inches. Calcium carbonate occurs nearer the surface on the knolls or other exposed places where the depth of the brownish layers is shallow. In those places where effervescence with an acid does not take place within a depth of 50 or 60 inches, the 30- to 40-inch surface layer is generally slightly acid and the material below gradually increases in alkalinity with depth.

In the central to east-central part of T. 138 N., R. 82 W., there are a few areas in which friable olive-drab silty clay lies at a depth of 2 to 3 feet (pl. 4). This clayey material appears to be glacial till, and the overlying sandy material has probably been transported by wind from more sandy areas to the west.

Areas with a claypan (solonized layer) constitute another variation from the profile described above. The surface layer in these areas is dark grayish-brown fine sandy loam that becomes lighter in color with depth. At about 6 inches there is an abrupt change to the hard and



A deep variation of Flasher fine sandy loam developed on shallow glacial till deposits over sandstone. The sharp color boundary, general lack of prismatic structure, and looseness of underlying calcareous material can be seen.

brittle dark coffee-brown fine sandy clay loam pan that breaks under considerable pressure into irregular angular pieces. Below a depth of about 10 inches the color grades to olive brown or olive drab and the texture varies from loamy fine sand to fine sandy clay loam. This material is not hard. It comes from place in irregular pieces that are easily crushed. Carbonates are at a depth of 14 to 20 inches. The surface of these claypan areas is pitted by depressed patches or pits 4 to 8 inches deep. The 2- to 3-inch surface layer in these pits is comparatively hard brittle fine sandy clay loam, below which is more friable sandy material similar to that underlying the areas not pitted. This claypan condition is so inextensive that the areas have been indicated on the soil map by scab-spot symbols.

Between 80 and 90 percent of Flasher fine sandy loam is tilled. Wheat occupies about 45 percent of the tilled area and corn and cane (sorghum) probably 20 percent. Other small-grain and hay crops occupy the rest. Because of its sandy character this soil is better adapted to the deeper rooted crops such as corn, cane, and potatoes. The more productive areas are well adapted to such root crops as potatoes. Rye is well suited to this soil. It does not winter-kill so easily on sandy soils as on heavier textured soils that are more subject to heaving, and it is ready to be harvested at a comparatively early date. Fall plowing is not so commonly practiced on this soil as on the silt loams and clay loams. The tilth of sandy soils is not benefited by winter freezing and thawing; and plowing in the fall, unless a fall-sown crop is established, only exposes the soil to wind action for a long period. Because of the likelihood of soil blowing, Flasher fine sandy loam should be protected as well as possible by a vegetative cover crop or by tillage methods designed to diminish soil drifting.

Crop yields vary considerably on this soil. They are decidedly low and irregular from year to year on the sandiest areas. The best areas, however, produce nearly as well as or even better than Williams silt loam, because of the ability of this soil to make better use of light showers during the summer. Wheat in average good years yields 10 to 12 bushels, oats 20 to 25, corn 22 to 26 bushels, and millet $\frac{3}{4}$ to $1\frac{1}{4}$ tons to the acre. Those few areas in which a claypan or a hardpan is developed are generally less productive than the regular type, and those areas that are severely pitted are probably best utilized for grazing.

The carrying capacity of average Flasher fine sandy loam is approximately 65 percent of that of Morton loam, and its value as a general cropland is from 60 to 80 percent of that of Morton loam.

Flasher loamy fine sand, smooth phase.—This is not an extensive soil. It has a total area of only 26.6 square miles. Most of it lies in the southern part of the county, in the vicinities of Flasher, Timmer, and Breien, associated with the other Flasher soils.

Internal drainage is generally excessive because of the sandy character of both the surface soil and the subsoil, and for the same reason, the water-holding capacity is low. The parent materials have been weathered principally from the sandstones of the Lance formation and to some extent from those of the Fort Union formation.

The native vegetation is a mixed stand of niggerwool and blue grama together with some dense patches of sandgrass. Blue grama

predominates in the depressions characteristic of a gently rolling surface, for it is in those places that surface moisture, and consequently organic matter and fine soil material, have a tendency to accumulate.

Flasher loamy fine sand, smooth phase, has the following profile characteristics:

- 0 to 15 or 20 inches, brown to dark-brown loamy fine sand that comes from place in irregularly shaped lumps that are easily crushed. The lower part of this layer is generally lighter in color than the upper part.
- 15 or 20 inches +, olive-gray loose fine sand. In places the sand may be very weakly cemented and may come from place as brittle angular fragments that crumble easily to fine sand when rubbed together. Calcium carbonate sufficient to cause effervescence when the soil is treated with acid occurs at varying depths between 2 and 4 feet.

On a few of the more exposed knolls or knobs the brown surface layer is thinner and carbonates may be abundant within a few inches of the surface.

About 50 percent of this soil is tilled. Corn occupies possibly 15 percent of the total acreage and the rest of the tilled acreage is used for wheat and other small grains for grain and hay. Although the sandy surface allows the ready penetration of rain and enables crops to make efficient use of moisture from light showers, yields of all crops are low and failures are comparatively frequent. Under favorable conditions corn may produce 20 to 25 bushels and wheat about 12 bushels an acre. With a moderate amount of tillage there is danger of severe soil blowing unless special tillage practices are followed. In general this soil, over a long period of time, is better suited to grazing than to cropland. The carrying capacity of virgin areas is about 45 percent of that of Morton loam.

GRAYISH-BROWN SOILS WITH CLAYPAN (SOLODIZED-SOLONETZ) AREAS

The soil complexes of the grayish-brown soils with claypan (solodized-Solonetz) areas represent areas of either Morton or Bainville soils that are so closely intermixed or intimately associated geographically with small areas or spots of the Rhoades soils as to make delineations between these two soils on the map impossible. The outstanding characteristic of the Rhoades series is a 3- to 7-inch thick comparatively dark dense clay layer at about 6 inches below the surface. The claypan is further distinguished by its columnar structure, which is a form of prismatic structure in which the tops of the individual prisms are rounded. In places the 6-inch surface layer has been removed (largely by wind action), leaving the claypan exposed in a more or less circular depression 2 to 15 feet in diameter. These depressions are locally known as scab spots, slick spots, or gumbo spots, and they have been aptly described as "smallpox on the landscape." The invariably pitted surface that results in a spotted cover of native grasses is the principal feature of the landscape that makes areas of these complexes easily recognized. The scab spots, however, are considerably less striking in character and number on these areas than on the areas of the next subgroup, which are the grayish-brown soils with numerous claypan (solodized-Solonetz) areas.

Because that part of the area affected by claypan and scab spots is less in the soils of this subgroup than in the soils of the next subgroup,

the name of the soil free of the claypan or scabbiness appears first in the compound name, whereas the complexes of the next subgroup are designated by a compound name in which the first name is that of the soil characterized by the claypan and scab spots. For example, one of the complexes of this subgroup is Morton-Rhoades clay loams, whereas Rhoades-Morton clay loams is a member of the next subgroup. Further information regarding the origin of these soil complexes may be obtained from the section on Morphology and Genesis of Soils.

The claypan layer and the scab spots detract from the value of these soils because of the interference they offer to tillage, to the availability of soil moisture for crops, and consequently to the growth of plants. These complexes in general, however, do not include those areas in which the claypan layer is so thick or dense or the scab spots so numerous that tillage is considered to be altogether impracticable. Largely because of their physical condition, these soils are better suited to small grain and grasses than to corn, potatoes, or other intertilled crops. Most of the tilled acreage is used for growing wheat, barley, oats, and flax. Western wheatgrass and crested wheatgrass are relatively well suited. Because of the texture and structure of the claypan, these soils are commonly prepared for sowing by fall plowing whenever the moisture condition of the soil is favorable, as the hard clods are broken to a more friable condition by subsequent freezing and thawing during the winter. Long-continued tillage, together with the effects of freezing and thawing, improves the tilth and productiveness of these soils from year to year.

Morton-Rhoades loams.—This soil complex represents areas of Morton loam in which smaller areas or spots of Rhoades loam are moderately distributed. Neither the density and thickness of the claypan nor the number of scab spots interfere sufficiently with the tillage and growth of crops to keep the areas out of cultivation. The areas are scattered throughout most of the county, although the greater part of them are in the vicinities of New Salem and Flasher. In general, the areas occupy positions similar to those of areas of Morton loam—the smooth ridge tops and upper slopes of the uplands. The average slope of all the areas is probably less than that of the areas of Morton loam. Surface drainage is slightly slower, and internal drainage is definitely slower. As with the Morton soils, the Fort Union and Lance are the underlying geologic formations.

The native vegetation of the areas between the scab spots is predominantly blue grama with some western wheatgrass and western needlegrass intermixed. The vegetation on the scab or clay spots varies considerably. A very few of these spots are unproductive and support only a scant growth of such plants as small pricklypear, gumweed, and saltgrass; a great many are occupied by a fair or patchy cover of buffalo grass and western wheatgrass; and others are completely covered with a growth chiefly of buffalo grass and to a smaller extent of western wheatgrass and blue grama.

The areas between the scab spots vary in their profile characteristics from soils of the Morton series to soils of the Rhoades series. A general description of one of the more common claypan (Rhoades) profiles in the interspot areas is as follows:

- 0 to 6 inches, dark grayish-brown friable loam. This is comparable to the surface horizon of Morton loam. The transition to the layer below is generally abrupt.
- 6 to 9 or 12 inches, dark-brown or dark olive-brown clay or sandy clay having a columnar structure. The surface of this layer not uncommonly is comprised of the rounded tops of the columns and has the appearance of the upper surface of a layer of biscuits. This surface generally is covered by a film or very thin layer of white or gray silt or very fine sand. When dry the soil of the columns is hard and dense and comes from place in hard sharply angular pieces $\frac{1}{4}$ to 1 inch in diameter. When wet the material is plastic and slick. Roots penetrate this layer evidently with difficulty, as they are less numerous than at a similar depth in Morton loam and most of them are seen to follow the vertical cracks separating the columns.
- 9 or 12 to about 20 inches, the material grades from the claypan condition to more friable material with a nearly olive-drab color. White flecks of carbonates are abundant except in the 2 to 3 inches immediately below the claypan.
- 20 inches +, laminated olive-gray and yellowish-gray silts and clays of the Fort Union and Lance formations.

The soil of the bare or nearly bare scab spots has the following general characteristics:

- 0 to $\frac{1}{4}$ inch, gray semicrust of very fine sand.
- $\frac{1}{4}$ to $1\frac{1}{2}$ inches, grayish-brown or dark grayish-brown silty clay loam that is fairly friable.
- $1\frac{1}{2}$ to $3\frac{1}{2}$ or 4 inches, very dark grayish-brown fairly hard dense clay resembling the claypan described in the preceding profile description.
- 4 to 6 or 8 inches, transitional to olive-drab silty clay.
- 6 or 8 inches +, olive-drab silty clay with an abundance of white flecks of carbonates. The material is hard in place but crushes fairly easily when subjected to firm pressure.

Variations exist from place to place in the details of the profiles of the scab spots as well as in those of the interspot areas, but the above descriptions are generally representative.

Over 85 percent of this complex is tilled. Small grains, particularly wheat, are the most common crops. Wheat is grown on more than 50 percent of the total acreage. Other crops are oats, barley, hay, and corn, but the relative acreage of corn is less than on Morton loam. Wheat yields 10 to 13 bushels, oats 22 to 26 bushels, and corn 20 bushels an acre in average good years. The carrying capacity for grazing is about 75 percent of that of Morton loam; consequently areas of this complex are considered good for grazing.

Morton-Rhoades clay loams.—This soil complex is similar to Morton-Rhoades loams except that the texture of the surface soil of the interspots is clay loam instead of loam. The parent materials of the Fort Union and Lance formations underlying the areas of this complex are more nearly pure clays, whereas those underlying areas of the Morton soils are clays and silts of the same formations. The position in the uplands and the surface drainage of Morton-Rhoades clay loams are the same as for Morton-Rhoades loams. Internal drainage, however, is somewhat slower because of the more uniformly heavy texture of the soils and underlying materials.

The native vegetation consists principally of blue grama and western wheatgrass. This soil complex occurs principally in the central part of the county, particularly in the vicinity of New Salem. The aggregate area is 32.7 square miles.

Between 85 and 90 percent of this soil complex is cropland. Wheat, small grains, flax, millets, and corn are the important crops, but the

relative acreage of corn is probably less than on Morton-Rhoades loams. In average good years, wheat yields 10 to 13 bushels, oats 22 to 26, and corn about 20 bushels an acre. The carrying capacity of virgin areas is about 75 percent of that of Morton loam.

Bainville-Rhoades loams.—This soil complex represents areas of Bainville loam, smooth phase, intermixed with smaller areas of Rhoades loam. The principal differences between these areas and those of Morton-Rhoades loams are in the thinner and lighter colored surface soil layer of the interspot areas and in the slightly more undulating position on ridge crests and knolls. The general occurrence of the scab spots, the range in the character of and the depth to the claypan, the surface and internal drainage, and the native vegetation are in general similar to those characteristics and conditions in areas of the Morton-Rhoades complex. Most of the small and scattered areas of Bainville-Rhoades loams are in the western part of the county, north and south of Glen Ullin and west to the Stark County line.

The principal use of the land is for wheat, other small grains, hay crops, and corn, although this soil complex is used more for grazing and wild hay than the corresponding complex of Morton-Rhoades loams, chiefly because of the lower productivity and suitability of Bainville loam, smooth phase, as compared with Morton loam. Yields are somewhat lower than on Morton-Rhoades loams complex, and the value for grazing is also slightly lower.

Bainville-Rhoades clay loams.—This soil complex represents areas of Bainville clay loam, smooth phase, intermixed with smaller areas of Rhoades clay loam. This complex is similar to that of Bainville-Rhoades loams because both complexes occupy about the same positions on the undulating to gently rolling upland ridges, slopes, knolls, and saddles, and both complexes have the same general distribution of scab spots. The principal differences are those associated with differences between loam and clay loam textures. The total acreage of this complex is 19.1 square miles. Most of the areas are relatively small and are scattered over the western half of the county.

The internal soil characteristics range from those of Bainville clay loam to those of Rhoades clay loam, depending upon the particular part of the complex that is examined.

Bainville-Rhoades clay loams complex is used for the same crops and managed in the same general way as Bainville-Rhoades loams complex. Average yields and the carrying capacity as range land are approximately the same for the two complexes, although the heavier texture of the clay loam soils increases the difficulty of tillage and probably lessens the amount of available moisture for plants during the summers marked by scattered light showers.

GRAYISH-BROWN SOILS WITH NUMEROUS CLAYPAN (SOLODIZED-SOLONETZ) AREAS

The grayish-brown soils with numerous claypan (solodized-Solonetz) areas differ from the soils of the preceding subgroup in having more scab spots and in the greater extent of the claypan in the areas between the scab spots. In these areas the scab spots and the claypan development dominate all other soil features to such a degree that the areas are not considered suitable for tilled crops. The surface has a somewhat choppy or rippled appearance. The scab spots or clay spots are irregular in outline and range from 3 to 20 feet in diameter.

They occupy the low positions or depressions that lie from 4 to 12 inches lower than the surrounding interspot areas. These depressions represent from 15 to 40 percent of the areas of the soil bodies. Vegetation, especially grass, is generally sparse or entirely lacking.

The interspot areas, or higher parts that make up the remaining 60 to 85 percent of the soil bodies, represent that part in which the claypan has not been exposed by differential erosion, together with the areas that have no claypan. Thus the claypan in the interspot areas varies both in degree of development and in extent. The most common variations are in the thickness and color of the surface layer, the thickness of the claypan layer, and the abruptness of the change from the comparatively friable surface layer to the hard, intractable claypan. Almost all of the interspot areas support a good cover of vegetation consisting principally of grasses desirable for grazing. Because of the impossibility of showing on the published soil map all the various soil conditions that exist within short distances, these areas are recognized as complexes.

A generalized description of the interspot areas representative of the grassed-over Rhoades soils follows:

(1) A friable 6-inch surface layer of loam or clay loam, underlain by (2) a comparatively dark, hard, and dense claypan 3 to 7 inches thick, that generally has a distinct columnar structure. Below this the material gradually becomes less hard and lighter colored, and (3) at a depth of about 16 inches olive-drab fairly hard but somewhat friable clayey material is reached. Calcium carbonate sufficient to cause effervescence when the soil material is treated with an acid is reached in most places 2 or 3 inches below the lower surface of the claypan.

A generalized description of the eroded Rhoades soil or clay spot follows:

A quarter-inch thick semicrust of somewhat gray very fine sand underlain by a 2- or 3-inch layer of comparatively dark clay having a hard resistant consistence and structure. This clay is hard when dry and slick and plastic when wet. Moisture penetrates slowly. This is underlain by material similar to that below the claypan layer of the interspot areas.

For more information regarding the morphology and genesis of these solodized-Solonetz complexes, reference may be made to the section on Morphology and Genesis of Soils, page 128.

Rhoades-Morton clay loams.—This soil complex consists essentially of an intricate pattern of claypan soil (Rhoades clay loam) and the associated scab spots and more limited areas of Morton clay loam. The preponderance of the claypan soil and associated scab spots is usually sufficient to discourage any attempt at tillage; therefore this complex is considered locally as grazing land, whereas areas of Morton-Rhoades clay loams complex, with a smaller proportion of claypan and scab spots, is considered to be tillable land.

As with Morton clay loam and Morton-Rhoades clay loams complex, areas of Rhoades-Morton clay loams complex are gently undulating to gently sloping with good surface drainage. Internal drainage, however, is slow because of the claypan and the heavy texture of the soil and parent materials that have been derived from the silts and clays of the Fort Union and Lance formations. Most of the acreage is in the vicinity of New Salem and to the east.

In these complex areas soil conditions vary within short distances, and it is impossible to show such areas separately on the published soil map of the scale used. A particular interspot area of Rhoades-

Morton clay loams may contain any one or all three of the following soil conditions: Morton clay loam, Rhoades clay loam, or an intermediate or transitional condition between the two. A description of Morton clay loam appears on page 38 of this report.

The following is a description of Rhoades clay loam in the interspot area:

- 0 to 5 inches, dark grayish-brown or grayish-brown friable clay loam that crumbles easily. The contact between this layer and the one below is generally sharp and distinct.
- 5 to 10 inches, hard, dense, dark grayish-brown or very dark grayish-brown clay. When removed from place the material breaks into hard angular fragments that are very resistant to further crushing. The surface of this layer generally has a film or coating of gray very fine sand.
- 10 to about 15 inches, color becomes lighter and the hardness less pronounced. Effervescence is usually visible when the soil is treated with an acid at 2 or 3 inches from top of layer.
- 15 inches +, olive-drab or olive-gray clay with numerous white flecks of carbonates.

A description of Rhoades loam in the scab spots (also known as clay spots, gumbo spots, and slick spots) as discussed on page 46 under Morton-Rhoades loams also applies to the scab spots of this complex except for slight differences in texture.

Because of their very small extent, a few areas of loam texture have been included on the soil map with the areas of Rhoades-Morton clay loams.

The native vegetation on the interspots is predominantly blue grama with some western wheatgrass, western needlegrass, prairie junegrass, and a few other grasses. Clubmoss is also common to these areas. Other plants include saltgrass, plantain, pasture sagebrush, gray sagebrush, and pricklypear. A large part of the scab spots is bare. The most common vegetation, when it is at all established, consists of a sparse growth of saltgrass, western wheatgrass, pricklypear, and annual weeds. Saltgrass and small pricklypear are the most persistent. During the moist years western wheatgrass makes a comparatively noticeable growth. In places, scab spots have a small amount of buffalo grass or blue grama on them.

Almost all of the acreage of Rhoades-Morton clay loams complex is used as grazing land. The carrying capacity is estimated to be about 30 percent of that of Morton loam.

Rhoades-Bainville clay loams.—This soil complex is similar to Rhoades-Morton clay loams complex except for the differences between the Bainville and Morton members of the complex. The Bainville soils are lighter in color and have a thinner dark surface layer, less pronounced prismatic structure, less depth to carbonates, and lower productivity than the Morton soils. On the other hand, areas of Rhoades-Bainville clay loams are similar to areas of Bainville-Rhoades clay loams except for the greater number of scab spots, the greater extent of the claypan condition in the interspots, and the general unsuitability for tilled crops.

The areas of this complex are small and scattered over the county. They occur in association with the other soils of the smooth and undulating uplands and those of the rolling uplands. The value for grazing is approximately the same as that of the Rhoades-Bainville loams.

SOILS OF THE ROLLING UPLANDS

The rolling uplands consist essentially of a combination of narrow smoothly rounded ridge tops and narrow draws or drainageways separated by slopes of 7 to 15 percent. The drainage channels through the draws are generally smooth enough to allow the driving of farm machinery across them. In some places, however, ditches have developed that are too wide and deep to allow this. Some of these ditches are a result of natural erosion, whereas others have been assisted in their growth by the destruction of the virgin sod in the drainageway by tillage.

About the same soil series are included in this group as were included in the smooth and undulating uplands. The soils on the smoothest parts of the ridges are comparable in color and depth to those of the normal types of the smooth and undulating uplands, whereas those in the small draws are generally thicker and darker colored. Most of these soils, however, are on the slopes and are generally thinner and include knobs here and there where the olive-drab or olive-gray material of the deep subsoil is exposed. The shallow condition is due to the less favorable moisture conditions that have hindered the production and accumulation of organic matter in the surface soil, and in some areas it is due to the removal of the surface soil by runoff water and action of the wind. On the other hand, the thicker and darker layers of the soils of the included narrow draws are due to the better moisture conditions and in some areas to the deposition of fine material from the adjoining slopes by runoff water.

So far as their slope is concerned, these soils are considered suitable for crops requiring tillage; but machinery, particularly heavy machinery, is handled with considerably greater difficulty than on the smoother areas. In general, surface drainage or runoff is apt to be excessive, especially on the steeper slopes; the depth of the comparatively fertile surface soil is markedly uneven; the more exposed areas are subject to considerable accelerated erosion if tilled; and soil fertility and productivity are lower than those same qualities of soils on smoother sites. In general, these soils are farmed in the same way as are the associated normal types of the smooth and undulating uplands, although a greater proportion of the total acreage is used for grazing, and a few other tracts occasionally lie idle.

DARK GRAYISH-BROWN SOILS

The two soils that represent the dark grayish-brown soils of the rolling uplands are the rolling phases of Morton loam and Morton clay loam. They resemble the normal types except that (1) they have a more rolling relief or greater degree of slope, and (2) they are more variable in soil character, particularly with respect to depth. Some of the areas, especially in the northeastern part of the county, are stony to very stony. Probably 50 to 60 percent of the total acreage is tilled. Yields are lower and the land is farmed with greater difficulty than on the smoother sites. On the other hand, the difference in grazing values between the two subgroups is not as great as the difference in values for cropping.

Morton loam, rolling phase.—This soil includes those areas of Morton loam that have slopes of 7 to 15 percent. The lay of the land

is rolling or billowy for the most part, although some of the areas are more definitely single slopes along the sides of hills, buttes, draws, or ravines. But these slopes in turn are usually dissected by transverse drainageways in sufficient degree to break the continuity of the single slope. Surface drainage is good to excessive, especially on the steeper slopes. The parent materials are the same as for Morton loam except that a few areas in the northeastern part of the county are underlain by olive-drab glacial till. Such areas are more properly classified as Williams loam, rolling phase; but because of the limited acreage and similar capabilities for use, they have been included with Morton loam, rolling phase. Glacial boulders occur on these and other areas, especially in the northeastern part of the county, where this evidence of glaciation is most striking. Such areas are shown on the soil map by stone symbols.

The total area of Morton loam, rolling phase, is 52.3 square miles. This soil occurs mostly in the vicinity of New Salem and to the east and northeast of that place.

The grass cover varies with the site conditions. On the smoother ridge crests the grasses are similar to those on Morton loam. In the draws the growth is denser and consists of blue grama, western wheatgrass, and some big bluestem. The grass cover on the slopes is noticeably inferior to that of either the draws or the included smooth ridge tops, because of the drier site and the poorer soil. It is composed principally of blue grama, niggerwool, needlegrass, and some little bluestem. The last three are much less desirable for grazing than blue grama and western wheatgrass.

The soil layers of Morton loam, rolling phase, are similar to those of Morton loam except that the depth to which the dark grayish-brown color extends varies according to the lay of the land. In the smoother parts, especially in the draws or lower areas, and on the tops of ridges the soil is identical with typical Morton loam; but on some of the steeper slopes and knobs the dark grayish-brown or dark-brown color extends to a depth of only a few inches. Many of the plowed fields of this soil show lighter colored patches, indicating that the dark color does not extend to the bottom of the plow layer. The discussion of Morton loam on page 36 may be referred to for a more detailed description of the soil profile characteristics. Some areas include claypan and scab spots. These are shown on the map by the scab-spot symbol and are described under the Morton-Rhoades and Rhoades-Morton complexes.

Probably 50 to 60 percent of the acreage is tilled. Much of the untilled soil is too stony for practical crop production. Approximately the same crops in about the same relative acreages are grown as on Morton loam. Wheat is the most important crop and is grown on more than one-half of the tilled acreage. Oats, barley, corn, flax, and millet are also grown. Yields range from 25 to 40 percent less than those on Morton loam because of the less favorable soil conditions. The land is farmed with greater difficulty because of the necessity of hauling machinery over the slopes and because the fields are generally more irregular in shape.

Areas that are not tilled furnish fairly good wild hay and grazing. The average carrying capacity is about 75 percent of that of Morton loam.

Morton clay loam, rolling phase.—This soil includes those areas of Morton clay loam that have slopes of 7 to 15 percent. It differs from Morton loam, rolling phase, chiefly in texture. The clay loam is more difficult to till, and the range in favorable moisture conditions is not so wide. More detailed and specific information on the soil characteristics and the agricultural importance and significance of this soil may be obtained by referring to the discussions on Morton clay loam and Morton loam, rolling phase.

GRAYISH-BROWN SOILS

The grayish-brown soils of the rolling uplands have (1) a thinner and slightly less dark surface soil layer, (2) a slighter depth to carbonates, and (3) a less well-defined prismatic structure than the dark grayish-brown soils of the rolling uplands.

Bainville loam and Bainville clay loam are the two soils composing this subgroup. They have a more rolling relief or a greater percentage of slope and are more variable in soil character, particularly with respect to depth, than Bainville loam, smooth phase, and Bainville clay loam, smooth phase.

Bainville loam.—This soil is the light-colored loam of the rolling uplands that has developed from materials of the Fort Union and Lance geologic formations. The slopes range from 7 to 15 percent, although smooth narrow ridge crests and depressions are included. Surface drainage and internal drainage are good to excessive.

The total area of Bainville loam is 106.1 square miles. It occurs rather widely throughout all the uplands of the county, but the most extensive areas are west of New Salem.

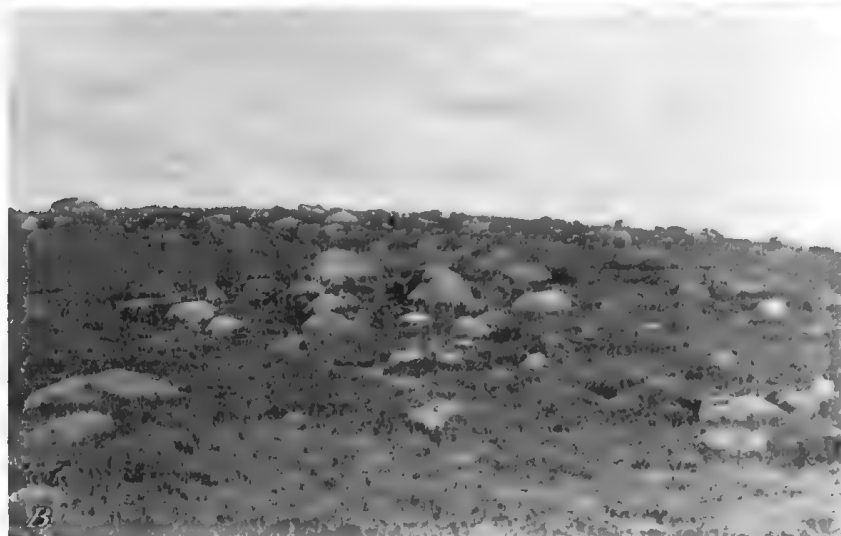
The native grasses are blue grama, niggerwool, needlegrass, and little bluestem. On the smoother ridge crests the stand is comparable to that on Bainville loam, smooth phase, but on most of the slopes niggerwool and little bluestem are more abundant than blue grama.

Bainville loam on the smoother crests has the following profile characteristics:

- 0 to about 5 inches, grayish-brown to dark grayish-brown friable soft loam that comes from place as irregular lumps that are easily crushed
- 5 to 8 or 9 inches, light grayish-brown loam with indistinct prismatic structure. There are sufficient carbonates to cause effervescence when the soil is treated with acid. Structure and color become less distinct with depth.
- 8 or 9 to 11 or 12 inches, brownish-gray to olive-gray silty material with white flecks of calcium carbonate.
- 11 or 12 inches +, gray and yellow laminated silts with abundant white flecks of carbonates.

The soil on the slopes is variable, particularly in regard to the depth of the surface layer over the underlying carbonates. In general the surface layer is more decidedly gray and thinner. On some of the knolls carbonates are at the surface or within 2 or 3 inches of it, and in cultivated fields the soil shows a mixture of the olive-gray material from the lower layers.

Glacial boulders are common on the surface of areas lying along the northern boundary or in the northeastern part of the county where the evidences of glaciation are greatest (pl. 5). A few areas in other parts of the county have hard, dense shale fragments on the surface. Where the boulders and rocks are in sufficient numbers to interfere seriously with tillage they are indicated on the soil map by stone symbols.



A, An artificial pond for watering livestock. Such ponds are valuable assets to the farm or ranch. The cultivated field in the background is on Bainville loam, smooth phase, and Bainville loam. The pasture is on a stony site of Bainville loam. **B**, Glacial boulders on Bainville loam. In some places this soil type is very stony. These areas are shown on the soil map by stone symbols and were designated as very stony land in the land classification project (8).

About 50 percent of the acreage of Bainville loam is tilled. Stoniness, steepness of slope, irregular occurrence with arable soils, irregular shape of individual tracts, and the relatively low fertility, water-holding capacity, and productivity are the principal factors that prevent this soil from being tilled. Wheat, other small grains, hay, and corn are the main crops. Yields are considerably less than on Bainville loam, smooth phase, and probably average about 30 percent less. The carrying capacity for grazing is about 60 percent of that of Morton loam.

Because of the relatively low yields, difficulty of handling machinery, susceptibility to losses by erosion, and consequently the increased cost of and need for careful management, it is probable that a large part of the acreage of this soil is better suited to permanent grazing than to crops that require cultivation.

Bainville clay loam.—This light-colored clay loam has developed from materials of the Fort Union and Lance geologic formations. The general landscape features and soil characteristics, except those associated with the clay loam texture, are similar to those of Bainville loam. Slopes range from 7 to 15 percent, although smooth narrow ridge crests and narrow depressions are included. Surface drainage is good to excessive, and internal drainage good to fair.

The total area of Bainville clay loam is 50.4 square miles. It is rather widely distributed throughout the uplands of the county, but the most extensive areas lie west of New Salem.

The native grasses are blue grama, niggerwool, needlegrass, and little bluestem. On the smoother ridge crests the stand is comparable to that on Bainville clay loam, smooth phase; but on most of the slopes niggerwool and little bluestem are more abundant than blue grama.

A profile of Bainville clay loam on the smoother crests has the following characteristics:

- 0 to 4 or 8 inches, dark-brown or dark grayish-brown to grayish-brown friable clay loam. This layer in places approaches a very dark grayish-brown color.
- 4 or 8 to 10 or 14 inches, grayish-brown clay loam with indistinct prismatic structure. The prisms crush easily to a fine-grained mass under slight pressure. Some areas, particularly those with the darker colored surface layer, have a fair prismatic structure. When treated with acid effervescence generally takes place throughout the layer, and white flecks of calcium carbonate are numerous, particularly in the lower half of this layer.
- 10 or 14 to 18 or 22 inches, brownish-gray to olive-gray clay loam without prismatic structure.
- 18 or 22 inches +, comparatively unaltered olive gray laminated clay of the underlying geologic formation.

On the slopes, which constitute the greater part of the areas, the depth of the dark-brown surface layer is variable, and in places carbonates may be at or within a very few inches of the surface. The plow layer of cultivated fields generally includes olive-gray material from the lower layers.

Glacial boulders are common on the surface of those areas of Bainville clay loam that lie along the northern boundary or in the north-eastern part of the county where the evidences of glaciation are greatest. A few areas in other parts of the county have hard dense shale fragments on the surface. Where the boulders and rocks are in suffi-

cient numbers to interfere seriously with tillage they are shown on the soil map by stone symbols.

About 50 percent of the acreage of Bainville clay loam is tilled. Stoniness, steepness of slope, irregular occurrence with arable soils, the irregular size and shape of individual tracts, relatively low fertility and productivity, difficulty of tillage, and the narrow range of optimum moisture conditions are the principal factors that keep this soil out of tillage. About the same crops are grown and the same yields are obtained as on Bainville loam. Wheat is the principal crop, and this with oats, barley, flax, millet, other hay crops, and corn accounts for the acreage of tilled land. In favorable years wild hay is important on some of the areas. Yields of all crops probably average about 30 percent less than on Bainville clay loam, smooth phase, and the carrying capacity for grazing is about 60 percent of that of Morton loam.

Because of the relatively low yields, difficulty of handling machinery, susceptibility to losses by erosion, and consequently the need for careful management of this soil, it is probable that a large part of the acreage of this soil is better suited to permanent grazing than to crops that require tillage. The losses from soil blowing are somewhat less than on Bainville loam.

REDDISH-BROWN SOILS

The reddish-brown soils of the rolling uplands differ from the Morton and Bainville soils in the color of the soil layers and in being underlain by scoria beds. The scoria beds have evidently been formed from shale by the burning of the underlying lignite beds. Searing loam, rolling phase, differs essentially from Searing loam in having a greater slope gradient and in the more variable thickness of the soil layers above carbonates.

Searing loam, rolling phase.—This phase differs from typical Searing loam in that its surface is more rolling or billowy, low knobs or outcrops of scoria are numerous, and the depth of the reddish-brown or dark-brown soil layer is more variable. Most of the individual areas do not occupy more than 15 to 20 acres. Most of this soil occurs in the western part of the county, west of New Salem, and in the hilly district east and southeast of Glen Ullin.

The scoria knobs have a variable quantity of reddish-brown loam or silt loam material intermixed with scoria fragments to a depth of 3 or 4 inches. The underlying material is almost wholly reddish scoria fragments. The soils of the limited areas between the scoria knobs differ from place to place in the color of the surface, in texture, and in the development of prismatic structure.

The vegetation on the knobs is sparse and is generally composed of little bluestem, scattered shrubs, and creeping juniper. The vegetation of the intervening areas affords fair to good grazing and consists chiefly of blue grama intermixed with some western wheatgrass and saltgrass. The scab spots are bare or nearly so. Some of the draws or drainage-ways are well drained and have a good grass cover of mixed blue grama and western wheatgrass with some big bluestem in places.

Practically all of Searing loam, rolling phase, is used for grazing. The carrying capacity is estimated to be about 55 percent of that of Morton loam. Prevention of overgrazing is probably the most impor-

tant contribution that management can make to the maintenance and continuance of the range capacity of this soil.

DARK GRAYISH-BROWN TO BROWN SANDY SOILS

The dark grayish-brown to brown sandy soils of the rolling uplands are members of the Flasher series. The soils of this subgroup differ from the dark grayish-brown to brown sandy soils of the smooth and undulating uplands in having (1) a more rolling or sloping surface and (2) a more variable soil character, particularly in respect to depth of the dark surface layers above the layer of carbonate accumulation. The slope ranges from 7 to 15 percent. These soils are more droughty than the soils of the Morton, Bainville, and Searing series, and they appear to be better suited to deep-rooted crops, such as corn and sorghums, than to shallow-rooted small-grain crops. The sandy porous surface soils, however, allow crops to make more efficient use of the moisture from light summer showers than the loams and clay loams of the first three subgroups. On the other hand, these soils are of low natural fertility and are markedly subject to soil blowing. This characteristic together with the rolling relief limits the suitability of these soils for tillage purposes. The more droughty and porous character of Flasher loamy fine sand makes it less desirable for cropping or grazing purposes than Flasher fine sandy loam, rolling phase.

Flasher fine sandy loam, rolling phase.—This is the most sandy soil of the rolling uplands that is generally tilled. The slopes range from 7 to 15 percent, although narrow smooth ridge crests and small draws are included with the areas shown on the soil map.

The total area is 41.2 square miles. A large part of this is in the southwestern part of the county in the vicinity and east of Flasher.

Internal drainage except in the draws is excessive, as the sandy nature of the subsoil and substrata permits a large part of the moisture received to be lost by rapid percolation. Loss by runoff, on the other hand, is not great.

The native vegetation is similar to that of Flasher fine sandy loam, but the proportion of blue grama is somewhat less and that of nigger-wool correspondingly more. Little bluestem and scattered patches of sandgrass are common on the steeper parts.

On the smoother crests and slopes Flasher fine sandy loam, rolling phase, has the following profile characteristics:

- 0 to 8 or 9 inches, dark grayish-brown or dark-brown fine sandy loam with coarsely prismatic structure. The soil comes from place as fairly brittle irregular prisms and chunks.
- 8 or 9 to 18 or 21 inches, the color grades from dark grayish brown or dark brown to olive brown, and the texture becomes coarser. Structural units become less well-defined.
- 18 or 21 to 28 or 31 inches, olive-brown loamy fine sand that comes from place as irregular chunks that crush easily with a little pressure to single grains or small aggregates.
- 28 or 31 to 60 inches +, olive-yellow or olive-drab loose fine sand. Effervescence with an acid takes place at varying depths through this horizon.

The principal and most noticeable variation in profile features is the depth to carbonates. They lie at a depth of 3 feet or more in the smoother areas or where wind-drifted material has accumulated, whereas on the exposed knobs and steeper slopes they are at the surface. A few small areas of Cheyenne fine sandy loam, rolling phase, have

been shown on the soil map as Flasher fine sandy loam, rolling phase, because of the very limited acreage and the general similarity of the character and use of the two soils.

About 50 percent of Flasher fine sandy loam, rolling phase, is tilled. Where tilled it is markedly subject to blowing or wind drifting, especially the areas on the more exposed slopes or knobs. Wheat is the most important crop, followed by corn and sorghum cane. Other small grains and hay crops occupy the rest of the tilled acreage. Rye, corn, sorghum, and potatoes are the best adapted crops. Yields are lower than on the typical soil, and the soil is not considered to be very productive or desirable, because of its droughty character. Better air drainage on the more rolling slopes probably accounts for the lower loss of wheat on the rolling phase than on the typical soil in years of infestation by black stem rust. The grazing value is slightly better than half of that of Morton loam. The relatively low productivity, together with the unfavorable relief and texture that favor soil blowing when the soil is tilled, renders this soil better suited for permanent grassland than for cropland. The most improved practices of tillage are needed in order to reduce to the minimum the losses by soil blowing, and provision must be made for the incorporation of organic matter and the application of available supplies of some nitrogen, phosphorus, and potassium, if productivity is to be maintained.

Flasher loamy fine sand.—This soil has formed over the sandstones of the Lance, Fort Union, and Fox Hills formations. Slopes range from 7 to 15 percent. The succession of slope, crest, slope, depression, and slope that is common to Flasher fine sandy loam, rolling phase, is also common to Flasher loamy fine sand, although probably a greater proportion of the total area occupies slopes that are slightly steeper. In the Flasher series the rolling relief is most commonly associated with the loamy fine sand type and the undulating to gently rolling relief with the fine sandy loam type. Drainage, particularly internal drainage, is excessive.

The total area mapped is 50.5 square miles. Flasher loamy fine sand is widely distributed over the county, occurring almost invariably wherever the underlying slightly consolidated sandstone formations lie close to the surface. The most extensive areas are in the watershed of the Cannonball River in the southern part of the county, in the vicinities of Flasher, Timmer, and Breien.

The native vegetation is predominantly niggerwool associated with numerous dense stands of sandgrass. Blue grama intermixed with niggerwool grows on the smoother ridge tops, and some big bluestem associated with the niggerwool and blue grama forms a comparatively good stand of grass in the draws.

The following profile is common on the less rolling sites:

- 0 to 10 inches, dark-brown or brown loamy fine sand that comes from place as irregular-shaped lumps that are easily crushed.
- 10 to 15 inches, brown or light-brown loamy fine sand.
- 15 inches +, olive-gray loose fine sand.

In general carbonates occur at about 18 to 30 inches below the surface. In places the olive-gray loose fine sand is weakly cemented at a depth of 30 to 40 inches. This material comes from place as brittle angular fragments that crumble to fine sand if they are rubbed together.

The great part of this soil that occupies the slopes has a thinner brown surface layer that is about 5 to 6 inches thick. Carbonates are generally within a depth of 6 to 12 inches below the surface. The most exposed knobs have a very thin brown surface layer, and in such places carbonates are abundant to the surface.

Only a very small part of Flasher loamy fine sand is tilled. Under the stimulus of high prices for wheat during and after World War I, some of the areas were cropped at that time, but low prices and drought years soon brought about their abandonment as cropland. Such areas are easily identified by the weed growth that springs up annually, as it is very difficult to reestablish a stand of the native grasses after the soil has once been plowed.

Flasher loamy fine sand is not suitable for tilled crops, primarily because it is subject to soil blowing, is droughty, and has a relatively low level of inherent fertility. The hazards of crop production on this soil and the obstacles that are inherent in the reestablishment of the native grasses are very strong arguments against the use of any areas of it as tilled cropland. This soil makes fairly good grazing land, and its carrying capacity is about 30 percent of that of Morton loam.

GRAYISH-BROWN SOILS WITH CLAYPAN (SOLODIZED-SOLONETZ) AREAS

The grayish-brown soils with claypan (solodized-Solonetz) areas of the rolling uplands consist of areas of the rolling phases of either Morton or Bainville soils in which occur smaller areas or spots of the Rhoades soils. The Rhoades series has a comparatively dark dense claypan layer from 3 to 7 inches thick at about 6 inches below the surface. The claypan is further distinguished by its marked columnar structure, a form of prismatic structure in which the tops of the prisms are rounded. In places the 6-inch surface layer has been removed (largely by wind action) and the claypan is exposed in circular or elliptical depressions that range from 2 to 15 feet in diameter. These depressions are known locally as scab spots, slick spots, and gumbo spots. The soils of this subgroup differ from those of the corresponding subgroup under smooth and undulating uplands in having steeper slopes and greater variations in the depth to calcium carbonate (lime) from place to place.

Morton-Rhoades clay loams, rolling phases.—This soil complex consists of areas of Morton clay loam, rolling phase, in which are scattered smaller areas of Rhoades clay loam, rolling phase. These areas are most common in the vicinity of and northwestward from New Salem. They are inextensive, however, and are distributed irregularly. Except for the rolling land, these areas are similar to those of Morton-Rhoades clay loams. This soil complex is not well suited to the growing of crops requiring tillage.

The average slope of this soil ranges from 7 to 15 percent, and most of the areas are on slopes and included draws rather than on the crests. Another common site is the saddle between higher ridges.

The parent materials are the clays and silts of the Fort Union and Lance formations. The Rhoades soils appear to be associated in part with certain of the heavier clays that outcrop or come close to the surface on some of the slopes. The sloping or rolling land insures good surface drainage. The internal drainage of the Morton soils is good,

and that of the Rhoades soils is only fair. Glacial boulders are common to some of the areas, especially those in the northeastern part of the county. These areas are indicated on the soil map by stone symbols.

The grass cover of the interspot areas is similar to that on Morton clay loam, rolling phase, and consists principally of blue grama, niggerwool, needlegrass, and little bluestem. The cover on the scab spots varies, as they range from bare spots to comparatively well-grassed spots. Grama grass, western wheatgrass, and buffalo grass have completely covered some of the spots that formerly were bare. Small pricklypear, gumweed, and saltgrass occupy the less completely covered scab spots.

Less than 50 percent of Morton-Rhoades clay loams, rolling phases, is tilled. Much of the untilled part is too stony for crop production under prevailing methods and economic conditions. The land is farmed with difficulty because it is hard to use machinery on the slopes. The tilled areas are used largely for wheat and oats, and the untilled areas for wild hay and grazing. Yields are from 25 to 50 percent of those on Morton-Rhoades clay loams. Tilth is improved by fall plowing, and the scab spots are improved in tilth and productivity by manure and tillage.

Bainville-Rhoades loams, rolling phases.—This soil complex consists of areas of Bainville loam in which are scattered smaller areas of Rhoades loam, rolling phase. The total area is relatively small, and the individual tracts are small and scattered. They occur to the north and south of Glen Ullin and west to the Stark County line. Except for the rolling land, these areas are similar to those of Bainville-Rhoades loams. This soil complex is unfavorable for the growing of crops requiring tillage.

The slope of the land ranges from 7 to 15 percent. Most of the areas are on the shoulders and lower parts of slopes or on the saddles between ridge crests rather than on the crests themselves. Surface drainage is good to excessive, and internal drainage of the Rhoades soils is imperfect.

The native vegetation between the scab spots is a mixture of blue grama, niggerwool, needlegrass, and little bluestem on the areas that are Bainville loam; it varies from a mixture of blue grama, western wheatgrass, buffalo grass, and big bluestem to western wheatgrass, saltgrass, and little bluestem on the grassed portions of the Rhoades loam, rolling phase; and on the scab spots there are sparse stands of saltgrass, pricklypear, and gumweed.

The Bainville soils have a grayish-brown surface loam layer of irregular depth, underlain by another irregular layer of light grayish-brown loam, below which occurs brownish-gray to olive-gray silty material containing an abundance of calcium carbonate in the form of flecks. The Rhoades soils are characterized by the underlying relatively dark and dense claypan of distinct columnar structure and by scab spots here and there.

Since detailed descriptions of the Bainville and Rhoades series have been given respectively under Bainville loam (see page 52) and Morton-Rhoades loams complex (see page 45) and elsewhere in this report, no further detailed descriptions are given here.

Perhaps 20 to 30 percent of the areas are cropped to wheat and other small grains, and the rest is used for wild hay and grazing. Yields are less than on either Bainville loam or Bainville-Rhoades loams, because the scab spots, the greater slope, and less uniformly fertile soil lessen the productivity. Most of these areas should be used for wild hay and grazing instead of cropland, although the distribution of soils (soil pattern) on a few farms may justify cropping if careful management is practiced to maintain the soil and its productivity.

Bainville-Rhoades clay loams, rolling phases.—This complex consists of areas of Bainville clay loam in which are scattered smaller areas of Rhoades clay loam, rolling phase. These areas are similar to those of the Bainville-Rhoades loams, rolling phases, because both soil complexes occupy the same positions in the uplands, both have the same range of slope, both have approximately the same native vegetation, and both are used in about the same way. Soil texture is the essential difference between these two soil complexes. The greater clay content makes this complex slightly less desirable for tillage than the loam complex, because of the increased difficulty of tillage, the slower rate of infiltration of rain water, and the consequent increased loss by evaporation. These effects of the increased clay contents are not so noticeable in areas still in grass, and the relative suitability of the two kinds of complexes for grazing is approximately the same. This soil complex is not well suited to the growing of crops.

Since the characteristics of this soil complex are so definitely related to those of the other Bainville and Rhoades soils and soil complexes, no further descriptions of the soil conditions of this complex are given here.

The statements under Bainville-Rhoades loams, rolling phases, as to location of areas in the county, relief, native vegetation, use, and suggestions for use, apply also to the areas of this complex.

GRAYISH-BROWN SOILS WITH NUMEROUS CLAYPAN (SOLODIZED-SOLONETZ) AREAS

The grayish-brown soils with numerous claypan (solodized-Solonetz) areas of the rolling uplands differ from the soils of the preceding subgroup in having more numerous scab spots and in the greater extent of the claypan in the areas between the scab spots. In these areas the scab spots and the claypan development dominate all other soil features to such a degree that the areas are not considered suitable for tilled crops. The soils of this subgroup are similar to those of the grayish-brown soils with numerous claypan (solodized-Solonetz) areas of the smooth and undulating uplands, except for differences dependent on relief.

The surface of these areas has a somewhat choppy or rippled appearance. The scab or clay spots are irregularly round and range from 3 to 20 feet in diameter. They occupy low positions or depressions from 4 to 12 inches lower than the surrounding interspot areas. These depressions cover from 15 to 40 percent of the total area of the soil bodies. Vegetation, especially grass, is generally sparse or entirely lacking on the scab spots.

The interspot areas or higher parts making up the remaining 60 to 85 percent of the soil bodies represent that part in which the clay-

pan has not been exposed by differential erosion, together with the areas that do not have a claypan. Thus the claypan varies in extent and in its whole range of development in the interspot areas. The most common variations are in the thickness and color of the surface layer, the thickness of the claypan layer, and the abruptness of the change from the comparatively friable surface layer to the hard intractable claypan. Almost all of the interspot areas support a good cover of vegetation consisting principally of grasses desirable for grazing. Because of the impossibility of showing all the various soil conditions that exist within short distances on a map having the scale of the published soil map, these areas are recognized as soil complexes.

The interspot areas representative of the grassed-over Rhoades soils have a friable 6-inch surface layer of clay loam underlain abruptly by a comparatively dark, hard, and dense claypan from 3 to 7 inches thick. Below this the material gradually becomes less hard and lighter colored. At a depth of about 16 inches olive-drab fairly hard but somewhat friable clayey material is reached. Calcium carbonate sufficient to cause effervescence when the soil material is treated with an acid is reached in most places 2 or 3 inches below the lower edge of the claypan.

The eroded Rhoades soil (the scab spot) has a 2- or 3-inch surface layer of comparatively dark clay with a hard, resistant consistence and structure. This clay is hard when dry and slick and plastic when wet. This material is underlain by material similar to that below the claypan layer of the interspot areas. Drainage is slow. More information regarding the morphology and genesis of these solodized-Solonetz soil complexes may be obtained from the section on Morphology and Genesis of Soils (page 128).

Rhoades-Morton clay loams, rolling phases.—This complex consists of areas of Morton clay loam, rolling phase, intermixed with areas of Rhoades clay loam, rolling phase. The two soils are in such intimate geographical association that it is impossible to show each separately on the scale of the published map. This soil complex consists of the same soils as Morton-Rhoades clay loams, rolling phases, but the proportion of the Rhoades clay loam, rolling phase, is much greater. There are more scab spots, and the claypan condition is evident under the greater part of the interspot areas. Except for the steeper slopes (7 to 15 percent), these areas are also comparable to areas of Rhoades-Morton clay loams.

The areas of this complex are relatively small and are irregular in shape. They occur on the slopes and in the slight depressions that lie at the head of drainageways in the uplands. The total area is 0.7 square mile. Most of the soil complex occurs in the vicinity of New Salem. Surface drainage is good, but internal drainage is imperfect in most areas because of the underlying claypan. The parent materials are the clays and silts of the Fort Union and Lance formations.

The native vegetation on the interspot areas is largely blue grama mixed with little bluestem, needlegrass, niggerwool, prairie junegrass, and little clubmoss. On the areas transitional to the scab spots saltgrass, western wheatgrass, plantain, pasture sagebrush, gray sagebrush, and pricklypear are common. The stands vary with the past treatment and management.

For detailed descriptions of the profiles of the soils of this complex see the descriptions of Morton clay loam (page 38), interspot areas of Rhoades clay loam (page 58), and scab spots of Rhoades clay loam (page 46). Very little of Rhoades-Morton clay loams, rolling phases, is tilled, and practically all of it is used for grazing land. Its carrying capacity is slightly less than that of Rhoades-Morton clay loams, about half of that of Morton-Rhoades clay loams, rolling phases, and one-fourth that of Morton loam.

Rhoades-Bainville clay loams, rolling phases.—This soil complex consists of areas of Bainville clay loam intermixed with areas of Rhoades clay loam, rolling phase. The two soils are in such intimate geographical association that it is impossible to show each separately on the scale of the published map. This complex consists of the same soils as Bainville-Rhoades clay loams, rolling phases, but the proportion of the Rhoades clay loam, rolling phase, is much greater. There are more scab spots and the claypan condition underlies the greater part of the interspot areas. Except for the steeper slope (7 to 15 percent), these areas are also comparable to areas of Rhoades-Bainville clay loams.

The individual areas of this complex are small and scattered. They occur in association with the other Bainville soils of the rolling uplands, principally Bainville clay loams. They usually occupy saddles between ridges and the slopes below higher ridge crests. This complex has a total area of 0.2 square miles. The greatest acreage is in that part of the county west of New Salem. Surface drainage is good, but internal drainage is imperfect because of the underlying claypan. The parent materials are the clays and silts of the Fort Union and Lance formations. The native vegetation on the interspot areas is a mixture of blue grama, little bluestem, niggerwool, needlegrass, and a little clubmoss. Gumweed, saltgrass, pricklypear, gray sagebrush, pasture sagebrush, and western wheatgrass are some of the other plants that occur on the margins of the scab spots. The stands vary from place to place with the particular conditions of each site, including past treatment and management.

For detailed descriptions of the profiles of the soils of this complex, reference may be made to the descriptions of Bainville clay loam (page 53), interspot areas of Rhoades clay loam (page 49), and scab spots of Rhoades clay loam (page 46).

Very little of Rhoades-Bainville clay loams, rolling phases, is tilled, and practically all of it is used for grazing land. Its carrying capacity is about the same as that of Rhoades-Morton clay loams, rolling phases.

SOILS OF THE HILLY, STEEP, AND BROKEN UPLANDS

The hilly, steep, and broken uplands include all the areas with slopes in excess of 15 percent. Such areas in Morton County are considered too steep to be suitable for tillage. Farm machinery is operated with great difficulty, and the soils are generally droughty and markedly subject to erosion if tilled. Practically all of the areas are in their virgin condition. The character of the soil layers and of the natural vegetation is variable. The soil layers are not well developed over a large part of the area. The most desirable parts for grazing are generally in the draws or valleys, and the poorest are on the south-facing slopes. As the slopes become steeper the grazing becomes poorer, and

it is difficult for grass or brush vegetation to grow on slopes of more than about 80 percent. Many slopes are partly or wholly bare, depending on the steepness of the slope and the texture of the soil material. All steep or rolling areas, over 25 percent of which are composed of bare patches or tracts, are classified as Rough broken land.

GRAYISH-BROWN SOILS

The grayish-brown soils of the hilly, steep, and broken uplands are shown on the soil map as hilly and steep phases of Bainville loam and Bainville clay loam. In addition to the hilly and steep relief, these soils are characterized by relatively shallow grayish-brown surface layers underlain by olive-gray silt and silty clay material containing a considerable quantity of calcium carbonate. There is considerable variation in depth and character of soil, in plant cover, and in relief from place to place. These soils constitute a belt of rough land along the Missouri River, the Heart River, and their principal tributaries. Although the carrying capacity of these soils is only low to fair, they are of particular significance to grazing, because they comprise one of the more extensive grazing areas of the county and are of special value for winter grazing because of the protection the rugged topography affords from winter storms.

Bainville loam, hilly phase.—This soil is for the most part strongly rolling to hilly, with slopes of 15 to 30 percent, although it includes small valleys or draws and the smooth crests of narrow ridges. The surface soil layer resembles Bainville loam. Drainage is naturally excessive, and a great part of the rainfall is lost as runoff, particularly during hard showers. The underlying silts, clays, and soft shales of the Fort Union and Lance geological formations, because of their exposed position along stream valleys, are subject to the continued dissection by the geological processes of erosion, and consequently the development over them of the deeper, darker mature Morton soils has not taken place.

Bainville loam, hilly phase, is widely distributed over the county. The most extensive acreage is in the rough areas bordering the Heart River and Missouri River valleys (pl. 6). Isolated islandlike knobs are scattered throughout the rest of the county. The total area is 118.8 square miles.

A profile description of Bainville loam, hilly phase, is as follows:

- 0 to 4 inches, grayish-brown to dark grayish-brown friable soft loam that comes from place as irregular lumps that are easily crushed. This layer varies from 2 to 7 inches in thickness.
- 4 inches +, olive-gray material varying in texture from silt to silty clay with numerous white flecks of calcium carbonate.

There are numerous variations, even from this rather variable profile. In some places sandy patches, too small to be shown on the map as Flasher soils, have been included. In other places small tracts of Bainville clay loam, hilly phase, have been included. In a few places small smooth areas with dark grayish-brown layers 12 to 14 inches deep (Morton soils) have been included on the map because of their very small size. Along a few drainageways or draws where drainage is markedly retarded, areas of the Rhoades soils (soils with claypan) or areas with an excess of soluble salts have been included and are indicated by symbols. In that part of the county where the result of glaciation



A. A tributary draw of Alluvial loam soils, undifferentiated, leading to the Heart River valley. Such areas provide winter shelter and feed for livestock. The bordering hills consist of the hilly and steep phases of the Bainville and Flasher soils. Needlegrass is dominant in the foreground. **B,** The Heart River valley with Bainville soils in the foreground, a part of which are used here for wild hay.

is most distinct, boulders are strewn over the surface, and these are shown on the soil map by stone symbols.

The vegetation varies considerably. That on the smooth parts, particularly the broadest portions of the ridges and more gentle parts of the slopes, is composed of blue grama, needlegrass, and other good grazing grasses. Likewise the draws are generally occupied by blue grama and to a less extent by western wheatgrass, big bluestem, and other desirable grasses. These draws naturally afford the best grazing but represent only a very small part of the total acreage of this soil. The slopes, which occupy a large part of the area, have the poorest type of grazing vegetation. They are generally occupied by little bluestem with some blue grama and niggerwool intermixed. The south-facing slopes on the average have a less desirable grass cover, and growth is not so luxuriant as on the north-facing slopes. On many of the north-facing slopes there is a short scattered brush growth of buckbrush, silverberry, and juneberry. This growth is seldom dense enough to reduce the grazing value.

None of this phase is considered suitable for tillage, and practically all of it is used as grazing land at the present time. Small patches that are included in more extensive areas of cropped land are frequently tilled because of the greater convenience that results for working the smoother part. Yields do not justify their tillage, however, in any case. Although the carrying capacity of this soil is but 50 percent of that of Morton loam, it is considered desirable grazing land because of the fair to good type of grass cover it supports.

Bainville loam, steep phase.—This phase is similar to the hilly phase except that its average slope is more than 30 percent. The aggregate area is 49.2 square miles, distributed over the county. The most extensive areas are along the Heart and Missouri River valleys (pl. 6).

The natural vegetation is similar to that on the hilly phase except that on the slopes less desirable grasses are more predominant and the cover is thinner and less stable, and on the north-facing slopes brush growth is more common. The brush growth is composed of buckbrush, juneberry, buffaloberry, and some ash and aspen saplings. Creeping juniper is also common on the north-facing slopes, and where it predominates grazing grasses are scarce.

A profile description of Bainville loam, steep phase, is as follows:

- 0 to 2 inches, grayish-brown to dark grayish-brown friable soft loam. The thickness of this layer varies from less than 1 inch to 5 inches.
- 2 inches +, olive-gray material varying in texture from silt to silty clay with numerous white flecks of calcium carbonate.

All the variations described for Bainville loam, hilly phase, also occur to some extent in areas mapped as Bainville loam, steep phase.

Although the carrying capacity of this phase is low compared with that of Morton loam, the quality of the grass cover is fair to good. Also, as the hilly terrain affords protection from winds, it enhances the value of the more extensive areas as winter range (see pls. 9 and 10). The carrying capacity of this soil is about 30 percent of that of Morton loam.

Bainville clay loam, hilly phase.—This soil is similar to Bainville loam, hilly phase, except that the texture, especially of the surface

soil, is clay loam or clay. It differs from Bainville clay loam in having a hilly relief with slopes of 15 to 30 percent. The aggregate area is 63.3 square miles. This soil is widely distributed over the county. The largest areas are along the Heart River valley and in the hilly area between Glen Ullin and Almont.

The 4-inch surface layer is grayish-brown clay loam. The areas are less variable than those of Bainville loam, hilly phase, because sandy spots are less common; but the variations in stoniness and the inclusion of spots of Rhoades clay loam are about the same. The native vegetation is about the same as on Bainville loam, hilly phase, except that niggerwool and patches of sandgrass are less common on this phase. Bainville clay loam, hilly phase, is used entirely for grazing, and the carrying capacity is about 50 percent of that of Morton loam.

Bainville clay loam, steep phase.—This soil is similar to Bainville loam, steep phase, except that the texture, particularly of the surface soil, is clay loam or clay; and it is comparable to Bainville clay loam, hilly phase, except for its steeper slopes, which are over 30 percent. The aggregate area is 19.8 square miles, and it is distributed widely over the county. The most extensive areas are along the Heart River valley and in the hilly area between Glen Ullin and Almont. The native vegetation is about the same as that common to Bainville loam, steep phase, except that niggerwool is less common and sandgrass is practically absent. Like Bainville loam, steep phase, this soil is very shallow to the underlying olive-gray material, and except for the 2- to 3-inch surface layer, little true soil formation has taken place. It is used entirely for grazing, and the more extensive areas are particularly suitable for winter grazing because of the protection from wind that the steep terrain affords. The carrying capacity of this soil is about 30 percent of that of Morton loam.

REDDISH-BROWN LOAMS

The reddish-brown loams of the hilly, steep, and broken uplands are represented by Searing loam, hilly phase. Areas of this soil consist of a series of relatively small but steeply sloping scoria knobs that have a thin covering of soil and a fair stand of native grasses.

Searing loam, hilly phase.—This soil resembles Searing loam, rolling phase, except that it has a more hilly surface. The areas are composed of a series of small closely spaced and steeply sloping scoria knobs. In the less extensive intervening areas between the knobs are small areas of the Searing, Grail, Patent, Morton, and Bainville soils. Both surface drainage and internal drainage are good to excessive. The underlying materials are red scoria fragments and in places masses of clinkerlike scoria material.

The profile features of Searing loam, hilly phase, are similar to those of Searing loam, rolling phase, except for the generally shallower depth to the scoria fragments. Following is a description of a profile of Searing loam, hilly phase.

0 to 4 or 6 inches, dark reddish-brown loam.

4 or 6 to 12 or 15 inches, reddish-brown loam to silty clay loam with indistinct prismatic structure containing a considerable number of scoria fragments.

12 or 15 inches +, loose mass of scoria fragments.

The total area is 4.3 square miles. As is true of the rolling phase, most of the acreage of this soil is in the hilly area east and south of

Glen Ullin, and none of it is suitable for tillage. It affords a variable amount of grazing, with an average carrying capacity estimated to be about 25 percent of that of Morton loam. In some areas the scoria knobs are extensive enough to serve as sources of scoria for road-surfacing material.

DARK GRAYISH-BROWN TO BROWN SANDY SOILS

The dark grayish-brown to brown sandy soils of the hilly, steep, and broken uplands include the hilly and steep phases of Flasher loamy fine sand. Owing to the steepness of the slopes, the use of these soils for tilled crops is impracticable, and their loamy fine sand texture makes them too droughty to support the more desirable grasses. The surface layer of these soils is underlain by sandy beds and sandstone strata of the Lance, Fox Hills, and Fort Union formations. These soils occur as isolated knobs or as a group of hills above the general level of the surrounding country (pl. 1, C). The most extensive areas are along the Cannonball and Heart River valleys.

Flasher loamy fine sand, hilly phase.—This soil is similar to Flasher loamy fine sand except that the surface is hilly rather than rolling. The slope range is from 15 to 30 percent, whereas that of the regular type is from 7 to 15 percent. The principal native vegetation is niggerwool and dense patches of sandgrass. Blue grama occurs on the small smooth areas along the draws. Little bluestem is common on the exposed knobs. Some steep slopes bare of vegetation are included on the soil map because it is impossible to show them satisfactorily on a map of the scale used. This soil is widely distributed over the county, and the aggregate area is 76.5 square miles. The most extensive acreage is in the watershed of the Cannonball River.

The profile features are similar to those of Flasher loamy fine sand except that the 5- to 8-inch brown loamy fine sand surface layer is shallower to the underlying olive-gray loose fine sand and the depth to calcium carbonate is variable.

None of this soil is tilled. It is considered desirable range land, although the type of grazing vegetation is not so nutritious or palatable as that common on such soils as Williams loam or Morton loam. Its carrying capacity ranges from 15 to 25 percent of that of Morton loam, the lower value applying to those areas having considerable areas of sandgrass or of bare steep slopes.

Flasher loamy fine sand, steep phase.—This soil is similar to Flasher loamy fine sand, hilly phase, except that the areas occur on steeper slopes, the gradient ranging from 30 to 80 percent. In places some precipitous slopes have been included in the mapping of these areas. Such tracts or patches are generally partly or wholly bare. Soft sandstone outcrops are common but seldom occupy an extensive acreage. The aggregate area is 35.4 square miles, widely distributed over the county. The most extensive areas are along the Heart River and Cannonball River valleys. The native vegetation of niggerwool, sandgrass, and little bluestem is similar to that of the hilly phase except that the vegetation is thinner, the growth is slower, and little bluestem is more prevalent.

The soil profile features are even less pronounced than in Flasher loamy fine sand, hilly phase. The dark grayish-brown or brown surface layer is thinner, and it is entirely missing in those areas where

soft sandstone outcrops or where sandy areas have been made bare by the soil slipping down the slope. The surface layer averages 2 to 4 inches in depth over most of the areas, but its depth is variable from place to place.

Flasher loamy fine sand, steep phase, is used entirely for grazing, although the average grazing vegetation is neither so nutritious nor palatable as that common to such soils as Morton loam, Bainville loam, and Grail silty clay loam. The average carrying capacity ranges from 7 to 18 percent of that of Morton loam.

MISCELLANEOUS LAND TYPES

Miscellaneous land types include (1) Rough broken land and (2) Scoria. These land types consist of mapping units that cannot be identified by uniform soil characteristics, as little or no true soil development has occurred. They possess, however, certain physical characteristics of sufficient, even outstanding, significance to warrant recognition in land use. Neither type is tillable, and they have little value as grazing land, since they are rough and comparatively barren of vegetation. These conditions have been produced largely through the action of the geologic forces that are active in the dissection of the upland.

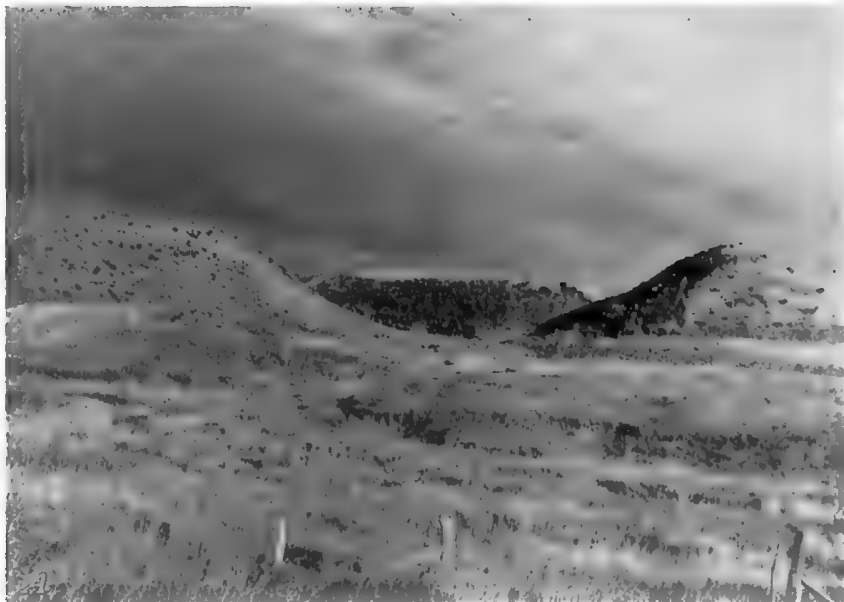
Rough broken land.—This land type includes all steep or rough areas where 50 percent of the surface is bare of brush, trees, and edible plants. Most of the areas consist of steep and comparatively bare slopes that are geographically associated with the hilly and steep phases of the Bainville soils. Some of the areas are isolated bare buttes, such as Twin Buttes northeast of Glen Ullin. The aggregate area of this land type is 7.8 square miles. Few of the individual areas occupy more than 40 acres. They are scattered throughout much of the upland part of the county, but there are only a few in the smoother parts. The most extensive acreage is in the Cannonball River watershed northeast of Breien.

Small patches of Flasher and Bainville soils are included, but the surface material for the most part is comparatively unaltered yellow-gray and olive-drab sand, silt, and clay of the exposed beds of the Fort Union and Lance geologic formations.

Most areas of Rough broken land are almost worthless, as there is very little edible vegetation growing on them. The grazing value of this land type is less than 10 percent of that of Morton loam.

Scoria.—This land type includes areas of exposed scoria beds and steep areas in which scoria forms most of the surface material. Very little if any true soil has developed. Most of the areas are either steep slopes or steeply rolling. The upper parts of the hills and ridges are invariably scoria, but generally the lower parts are gray or olive-drab clay of the Fort Union formation. The draws through the areas of scoria are generally narrow strips of Patent or Bainville soils that are too small to be shown separately (pl. 7, 4). The aggregate area of Scoria is 7.2 square miles. Most of the acreage is in the hilly area that lies east and southeast of Glen Ullin and northwest from Almont.

Scoria is composed mostly of fairly hard angular fragments of light-red or pink shale from 1 to 4 inches in diameter that have been formed



A, Characteristic relief and vegetation of the scoria hills between Glen Ullin and New Salem. Note the difference between the vegetation on the slopes and that in the draws. B, Scoria bank along highway between Glen Ullin and New Salem. The relative size and shape of the shale-like scoria fragments can be seen. Such sites are droughty and furnish only scanty grazing.

by the baking and fusing of clay overlying burning lignite beds (pl. 7, *B*). A small part of the material is composed of very dark reddish-brown hard clinker or slaglike masses ranging from 6 inches to several feet in diameter. The scoria beds vary from a few feet to 30 to 40 feet in thickness.

The steep slopes and ridges or hilltops are either practically bare or support only a very scant vegetation, a great part of which is nonedible. In some places a scant cover of blue grama, sandgrass, and little bluestem and other bunchgrasses occur. Ground cedar is common in many places, but it is of no value for grazing. The narrow strips of Bainville and Patent soils that are included along the small draws support a fair to good grazing vegetation. The relative acreage of these soils, however, is small. The carrying capacity of this land type ranges from 4 to 10 percent of that of Morton loam.

The shaly fragments of scoria are commonly used as road-surfacing material, particularly for the secondary roads.

SOILS OF THE DEPRESSIONS AND LOWER (CONCAVE) SLOPES

The soils of the depressions and lower (concave) slopes occupy depressions, such as narrow slightly sloping drainageways and sites of former ponds, in the uplands, and on the lower (concave) slopes spread as aprons at the bases of buttes, ridges, and higher uplands. These positions are the most favorable for an adequate supply of moisture, as they receive runoff from nearby higher land. As a result they support the most abundant growth of native grasses. The soils of some of these areas therefore contain more organic matter than any of the other soils in the county and so are the darkest in color. They are also the deepest over the underlying layer of calcium carbonate. These soils are members of the Arnegard, Timmer, and Grail series. Some areas are subject to recent deposition of local alluvium, and the soils in these places are young and light colored. These are the Patent soils. Some areas in the depressions and on the lower (concave) slopes are or have been subject to the accumulation of soluble salts, and others have claypans because of the influence of an excess of sodium. These are the Moline, McKenzie, and Dimmick soils.

VERY DARK TO DARK GRAYISH-BROWN SOILS

The very dark to dark grayish-brown soils of the depressions and lower (concave) slopes are represented by three soil series—Arnegard, Timmer, and Grail. The Arnegard and Timmer soils occur in the shallow drainageways and gentle depressions of the uplands, and the Grail soils are situated on the gentle lower valley slopes below more rolling uplands. These soils have developed from local alluvial-colluvial materials and are among the darkest, deepest, and most productive soils in the county.

Arnegard silt loam.—This dark-colored friable soil occupies the shallow drainageways and depressions of the uplands within areas of the Williams and Morton soils. The surface is gently sloping, and the areas generally lie in a position to benefit from runoff water from surrounding higher lying soils. Internal drainage, however, is sufficient to prevent the accumulation of soluble salts and to allow normal root development. Heavy rains may cause some of the areas to be

flooded temporarily. The soil is formed from alluvial material brought by runoff water from the surrounding soils of the uplands.

Arnegard silt loam is widely distributed over the county. The total area, however, is not large, amounting to 11.8 square miles, and the individual areas are small, since they occur as irregular strips along the shallow drainageways and gentle depressions in the smooth and undulating uplands.

The native vegetation is principally blue grama and western wheatgrass, the former predominating. Big bluestem is common, particularly on the narrower strips along the more defined drainageways. Patches of buckbrush are common on undisturbed areas.

A generalized profile of Arnegard silt loam is as follows:

- 0 to 6 inches, very dark grayish-brown soft friable silt loam. The reaction is slightly acid.
- 6 to 16 inches, very dark grayish-brown silt loam to clay loam with ill-defined prismatic structure. When taken from place with a spade, the soil breaks to nut-sized blocky (cubelike) fragments. The pieces are firm but under a little pressure crush to a soft crumbly mass. This layer in some places extends to a depth of 30 inches. The reaction is slightly acid to neutral.
- 16 to 22 or 35 inches, grayish-brown to brownish-gray clay loam to silty clay. This layer is transitional and becomes lighter in color with depth. Prismatic structure likewise disappears, but the soil material is friable.
- 22 or 35 inches +, olive-drab friable silty clay. The depth at which sufficient calcium carbonate is present to cause effervescence when the mass is treated with an acid varies from about 28 to 45 inches.

This is one of the most desirable soils of Morton County, and from 85 to 90 percent of it is tilled. Those areas not tilled are generally small tracts lying in areas of soils having a surface slope too great to be commonly farmed. Wheat occupies a large part of the acreage, and the remaining part is used mostly for oats, barley, and corn. Because of the high natural state of fertility and the exceptional position whereby the areas benefit from runoff water from the surrounding upland, yields average from 10 to 20 percent higher than those obtained on Williams silt loam, and they are somewhat more reliable during the dry seasons. Its favorable position relative to moisture supply, its high state of fertility, and its good tilth make this one of the most desirable soils for alfalfa, sweetclover, and the farm garden. On a few areas, however, especially during abnormally moist seasons, stands of alfalfa may be damaged as a result of temporarily insufficient drainage. As grazing land, Arnegard silt loam supports a vegetative cover of high quality, and in average seasons it has the highest carrying capacity of any of the soils of the county. Its carrying capacity is probably from 10 to 15 percent greater than that of Williams and Morton silt loams.

Timmer loam.—This soil differs from Arnegard silt loam principally in being underlain by sandy rather than clayey materials and in its loam texture. Most of the areas are small and irregular and are associated with areas of Flasher fine sandy loam in the southern part of the county in the vicinities of Flasher, Fallon, and Fort Rice. Drainage is good except for temporary periods of high runoff. The total area is 2.7 square miles.

The native vegetation is principally blue grama with some western wheatgrass and in places some big bluestem.

A generalized profile of Timmer loam is as follows:

- 0 to 6 inches, very dark grayish-brown loam (nearly a silt loam in some places).
6 to 18 inches, very dark grayish-brown loam or silt loam with fairly distinct prismatic structure. This layer is somewhat variable and may extend to 24 inches in depth.
18 to 28 inches, olive-yellow fine sandy loam grading into loamy fine sand.
28 inches +, loamy fine sand. When treated with an acid effervescence takes place generally at a depth greater than 28 inches.

Variations in the above profile occur. Some areas have a dark grayish-brown loam layer at a depth of 6 to 18 inches, with an irregular blocky or lumpy structure that crushes easily. There are a few areas in which olive-drab clay lies at a depth of 24 to 40 inches, immediately below the fine sandy loam layer.

The productivity of Timmer loam is comparatively high. It is used for the same crops as Arnegard silt loam, and yields are nearly as high. It is also one of the most desirable soils of the county for home gardens, and its characteristics should prove it to be likewise one of the best soils for alfalfa and sweetclover, although in abnormally moist seasons temporary periods of insufficient drainage may prove to be somewhat detrimental. The carrying capacity is about equal to that of Arnegard silt loam.

Timmer fine sandy loam.—This soil is developed on the sandy alluvium of the shallow draws and depressions of the uplands on which the Flasher soils predominate. Surface drainage is good, except that some areas are subject to temporary flooding by heavy rains. Internal drainage is good except for a few areas underlain by a mottled blue and yellow fine sandy loam subsoil. The areas are gently undulating to gently sloping. The most extensive acreage is in the SE $\frac{1}{4}$ T. 138 N., R. 84 W., and secs. 34 and 35 of T. 138 N., R. 82 W. Other areas are scattered throughout that part of the county south of the Heart River. The total area is 3.2 square miles.

A generalized profile of Timmer fine sandy loam is as follows:

- 0 to 5 inches, very dark grayish-brown fine sandy loam.
5 to 14 or 18 inches, very dark grayish-brown fine sandy loam that comes from place in irregular fragments that are easily crushed with a little pressure. Generally the lower few inches are slightly lighter in color.
14 or 18 to 28 inches, olive-brown fine sandy loam grading into olive-yellow loamy fine sand.
28 inches +, calcareous olive-yellow loamy fine sand. White flecks of calcium carbonate ordinarily are not above this depth.

A few areas have a mottled yellow and bluish-gray fine sandy loam layer below a depth of 16 inches.

The native vegetation is mostly blue grama with some big bluestem intermixed with it in places.

Most of Timmer fine sandy loam is tilled. Probably 50 percent of it is used for growing wheat and 15 to 20 percent for corn. The rest is used for the other small grains and hay. Yields are comparatively good. In average good years wheat yields from 12 to 15 bushels and corn from 20 to 30 bushels an acre. The few small areas with slow internal drainage are sufficiently well drained for most crops in average years. These spots, however, are not so well suited for the production of potatoes, alfalfa, and sweetclover as the well-drained areas. The relative value of Timmer fine sandy loam for cropland or for grazing is about 75 percent of that of Arnegard silt loam, the most productive soil in the county without irrigation. The sandy nature of this soil, however, requires that special care be taken to protect it from

blowing, although it is not so subject to blowing as the other fine sandy loams of the county. The higher content of organic matter and the occurrence of the soil in narrow draws tend to diminish soil blowing.

Grail silty clay loam.—This dark-colored heavy-textured fertile soil lies on gentle slopes below the upland. It is developed on local alluvial-colluvial material that has been brought down by runoff from the adjacent higher land. The relief is very gentle to gently sloping. Surface drainage is good, and internal drainage under normal conditions is satisfactory for plant growth, although it is somewhat retarded by the firm silty clay sublayers. As these areas lie between the soils of the uplands and the soils of the terraces and bottoms, the Grail soils are commonly associated with many of the other soils of the county (pl. 8 and pl. 9, *A*). The total area of Grail silty clay loam is 77.1 square miles. The most extensive area is in the vicinity of New Salem.

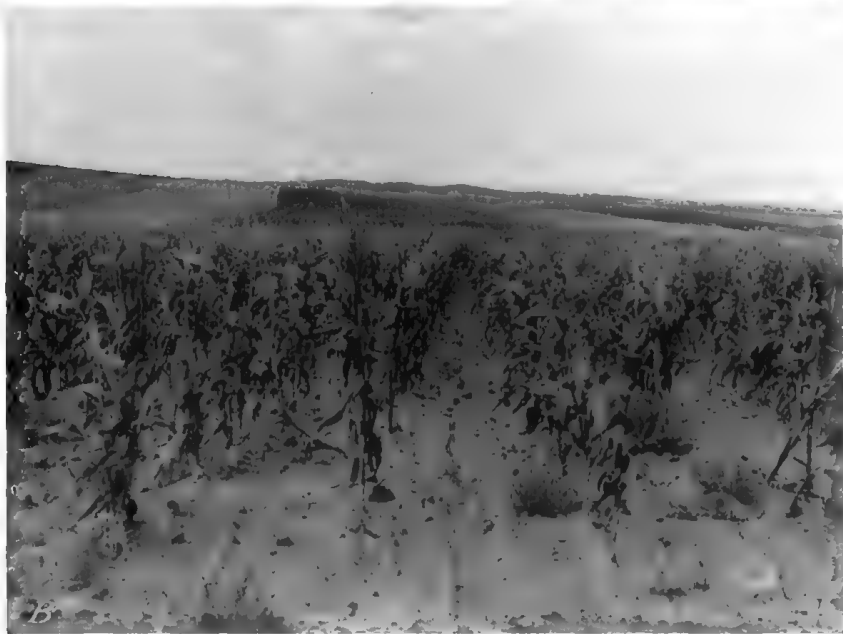
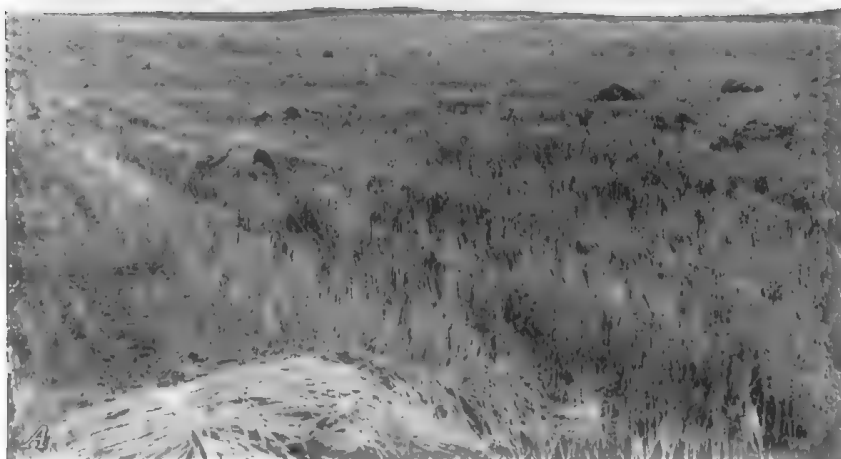
The native vegetation is a mixture of blue grama and western wheatgrass with a smaller quantity of such grasses as prairie junegrass and western needlegrass. Western wheatgrass predominates where grazing has not suppressed it. Because of the ability of blue grama to survive better under heavier grazing than western wheatgrass, it predominates on most areas.

A generalized profile of Grail silty clay loam (pl. 9, *B*) is as follows:

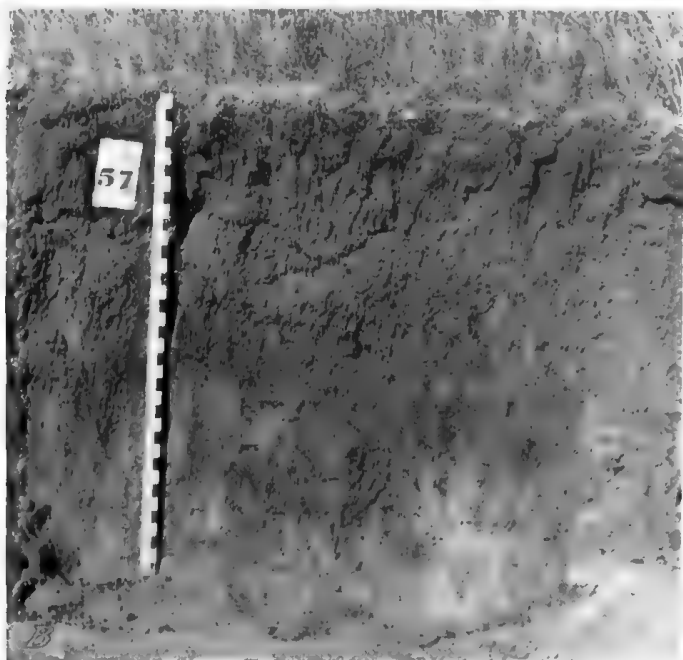
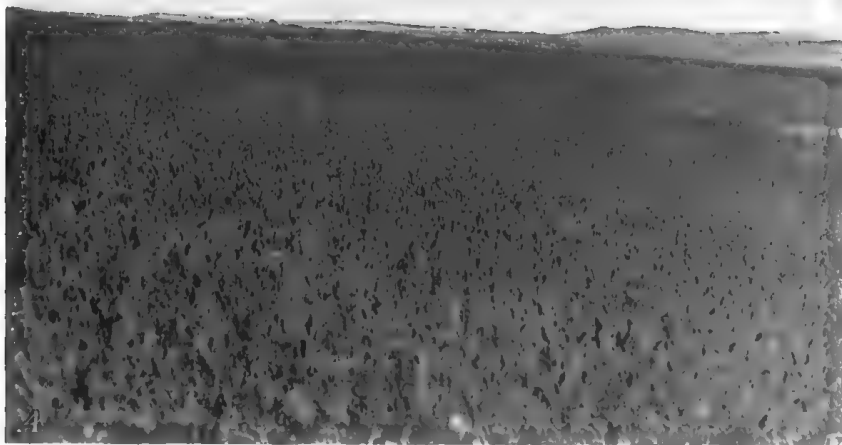
- 0 to 6 inches, very dark grayish-brown friable silty clay loam.
- 6 to 16 inches, dark grayish-brown silty clay loam with a well-developed prismatic structure
- 16 to 30 inches, transitional to olive-drab silty clay that breaks easily into angular pieces but offers more resistance to crushing than the material in the layer above. The prismatic structure becomes indistinct. Effervescence commonly takes place from 16 to 24 inches, and the white flecks of calcium carbonate are generally observable 1 to 2 inches below the depth at which effervescence first takes place.
- 30 inches +, olive-drab silty clay. The fragments are somewhat more friable than in the layer above, although in some places the mass is firm and resistant to digging. Carbonate flecks are less abundant than in the layer above.

In some places the prismatic structure of the layer at a depth of 6 to 16 inches is not well developed and the soil is fairly hard and comes from places in chunks that offer marked resistance to crushing. The depth of the soil varies somewhat with the degree of slope and the position on the slope. Generally the lower the location on the slope the deeper the soil. The areas with isolated patches of claypan and scab spots have been indicated on the map by the claypan symbol.

Grail silty clay loam is a desirable soil for crop production, and probably 85 percent of the total area is tilled. Wheat is the principal crop and occupies probably 55 to 60 percent of the total area. Barley, oats, corn, and hay are grown on the remaining tilled acreage. Reports of farmers indicate average yields as high as 19 bushels an acre for wheat in favorable seasons, and as high as 12 bushels for flax. Yields of all crops are comparatively good and average about the same as those obtained on Williams silt loam. In the two exceptionally dry years of 1934 and 1936 much of the corn that succeeded in producing at least a growth of forage was on areas of either Arnegard or Grail soils.



A. Wheat in shocks on Grail silty clay loam. Bainville, Morton, and Flasher soils in the distant background. **B.** Corn on Bainville loam, smooth phase, in the immediate foreground, and corn and wheat on Grail silty clay loam in the middle distance. The boundary between the two soils is easily seen. The soils of the hills in the background are principally types and phases of the Bainville, Flasher, Patent, and Grail series.



A, Millet, mostly on Grail silty clay loam. The higher part of the field in the background is Morton loam. Bainville, Flasher, Morton, and Grail soils occur in intimate association in the uplands in the background. **B**, A profile of Grail silty clay loam. The dark surface, prismatic structure, and underlying calcareous C horizon can be seen.

Grail silty clay loam is well suited to diversified or general farming. It is fertile, has a comparatively good tilth and a relatively smooth surface, and generally lies in a position to benefit from runoff water from the adjoining upland. It appears that the construction of terraces for the purpose of retaining more of the runoff would be beneficial.

The unplowed areas of this soil furnish very good grazing and have a comparatively high carrying capacity, about equal to or slightly greater than that of Williams silt loam.

Grail silt loam.—This soil is the dark-colored medium-textured fertile soil that lies on gentle slopes below the upland. It is developed on local colluvial-alluvial material that has been washed down from the adjacent higher land. The surface is gently sloping, and both surface drainage and internal drainage are good. The areas are situated on slopes in association with the Patent and with other Grail soils below the uplands that are composed of the Williams, Morton, Bainville, and Flasher soils. Grail silt loam is not as extensive as the silty clay loam. Most of the total area of 41.3 square miles is in that part of the county north of New Salem and Judson and on Custer Flats.

The native vegetation is a mixture of blue grama and western wheatgrass with smaller quantities of prairie junegrass and western needlegrass. The stand is similar in composition and density to that on Grail silty clay loam with the possible exception that probably there is relatively more grama grass and less western wheatgrass.

A generalized profile of Grail silt loam is as follows:

0 to 5 inches, very dark grayish-brown friable silt loam.

5 to 12 inches, very dark grayish-brown clay loam or silty clay loam with fair to good prismatic structure.

12 to 20 inches, transitional from very dark grayish-brown clay loam to olive-drab silty clay.

20 inches +, olive-drab silty clay that comes from place in well-defined angular chunks that crush only under firm pressure. Effervescence takes place at a depth of about 20 inches, and white flecks of calcium carbonate are abundant below 24 inches. The depth to carbonates varies within a range of about 6 inches over the county, but the above depths are most common.

In general, Grail silt loam is a friable soil throughout. There are a few areas, however, where the soil below 8 inches is fairly hard and when dug from place breaks into fairly hard irregular chunks rather than into easily crushed nut-sized pieces. Grail silt loam has been influenced by wash from the medium and lighter textured soils of the uplands, such as Morton loam, Bainville loam, and Flasher fine sandy loam. The underlying strata are generally heavy and firm, as they are relatively unaltered material of the underlying Fort Union formation.

Grail silt loam is used for the same crops as Grail silty clay loam, and the yields are equal to or slightly greater than on the heavier soil. Because of its silt loam texture, it is handled a little more easily and in general is more suitable for crops, particularly such as corn, potatoes, flax, millet, and alfalfa. On the other hand, its usual occurrence in smaller areas and strips than Grail silty clay loam offsets some of these advantages. The grazing value of the two soils is about the same.

Grail silty clay loam, slope phase.—This soil resembles Grail silty clay loam except that it lies on steeper slopes (7 to 15 percent) and has a more variable profile in respect to depth, texture, and structure of the several layers. A few small knobs of Bainville clay loam have been included in some areas, because of the impracticability of showing them separately on the soil map. Surface drainage is good to somewhat excessive, and internal drainage is slightly retarded. Some of the areas have glacial boulders scattered on and through the soil. Where the stones are numerous enough to interfere with tillage, symbols have been placed on the map. The areas of this soil occur in geographical association with the other Grail soils and with areas of Morton, Williams, and Bainville soils. The total area is 4.5 square miles.

The profile features are similar to those of Grail silty clay loam (page 70) except for a greater range in the variations in (1) thickness of upper layers above the zone of calcium carbonate accumulation, (2) distinctness of prismatic structure, and (3) the textures of the underlying layers.

Grail silty clay loam, slope phase, is one of the most productive soils in the county with a slope of 7 to 15 percent. Probably 75 percent of the total area is tilled. About the same crops are grown as on Grail silty clay loam, but yields average 15 to 25 percent less. General farming practices and methods of tillage are the same except that a somewhat greater proportion of the areas is left in grazing or cut for wild hay. The grazing value is estimated to be about 65 to 75 percent of that of Morton loam.

Grail silt loam, slope phase.—This soil resembles Grail silt loam except that it is more sloping (7 to 15 percent) and has a more variable profile in respect to the depth, texture, and structure of the several layers. Small knobs of Bainville loam have been included in some areas, because of the impracticability of showing them separately on the soil map. Surface drainage is good to somewhat excessive, and internal drainage is good. A few areas have glacial boulders scattered on and through the soil, and where they are sufficiently numerous to interfere with tillage, stone symbols have been added to the map. The native vegetation is similar to that on Grail silt loam except for the slightly smaller proportion of western wheatgrass.

Grail silt loam, slope phase, also resembles Grail silty clay loam, slope phase, except for texture and the more mellow consistence of the upper layer, a slightly more friable and less compact subsoil, and the inclusion of a slightly greater number of the small areas of Bainville soil. The areas lie on slopes below the uplands on which are located the soils of the Morton, Williams, Bainville, and Flasher soils. Areas of Grail silt loam, slope phase, have been influenced by wash from the medium and lighter textured soils of the uplands, such as Morton loam, Bainville loam, and Flasher fine sandy loam. The underlying strata are generally heavy and firm, as they consist of weathered material of the underlying Fort Union formation. Only a small total area of this soil (3.2 square miles) is mapped.

Grail silt loam, slope phase, is probably the most productive of the soils in Morton County having a slope of 7 to 15 percent. The silt loam texture of the surface layer facilitates the absorption of rain,

and the underlying heavier layers reduce the hazard of drought. Probably 75 percent of the total area is tilled. About the same crops are grown as on Grail silt loam, but yields average 15 to 20 percent less. Because of the silt loam texture, it is handled a little more easily and in general is more suitable for corn, potatoes, flax, and millet than is Grail silty clay loam, slope phase. Because of its slope, however, heavy machinery is operated with difficulty, and care is needed in order to minimize losses by runoff and soil blowing. The grazing value is comparable to that of Grail silty clay loam, slope phase.

BROWNISH-GRAY SOILS

The brownish-gray soils of the depressions and lower (concave) slopes are members of the Patent series that are developed in positions similar to those occupied by the Grail soils. The difference in color between soils of the two series is indicative of the relative time during which soil-forming processes have been operative on the local alluvium underlying the soils of the two series. In fact, the Patent soils are still subject to deposition and active erosion, especially in areas particularly subject to the accumulated runoff from the higher lands in the background. As mapped, these soils necessarily represent a range in conditions in respect to runoff, siltation, erosion, vegetative cover, and stage of soil development; and the several members of the series have individual significance as regards land use. Patent clay loam is very desirable for grazing and the production of wild hay and is fairly satisfactory for crops, whereas Patent clay loam, eroded phase, and Patent clay are of very little value even for grazing. A considerable range in the texture of the parent materials is shown by Patent loamy fine sand and Patent clay. Generally the Patent soils are developed on heavy materials.

Patent clay loam.—This light-colored heavy-textured soil lies on the gentle valley slopes. It is developed from clayey local alluvial-colluvial material washed from the immediately adjoining upland. The surface is gently sloping. Surface drainage is satisfactory for crop plants, although internal drainage is slow. This soil occupies the same general position in the landscape as does Grail silty clay loam, except that the hills in the background are generally steeper and subject to more runoff; consequently there is greater opportunity for deposition. Patent clay loam is scattered throughout that part of the county west of New Salem. Its total area is 10.5 square miles.

The native vegetation is a mixture of blue grama and western wheatgrass. Blue grama predominates except on the few areas that have not been grazed consistently.

A generalized profile of Patent clay loam is described in the following:

- 0 to 5 inches, dark-gray or brownish-gray friable clay loam that comes from place as fairly firm fragments that are easily crushed to a crumbly mass.
- 5 to 12 inches, fairly friable dark olive-gray silty clay with prismatic structure that breaks readily into nutlike fragments. These fragments are easily crushed to a crumbly mass. When treated with acid effervescence generally takes place at 8 to 10 inches.
- 12 inches +, fairly friable olive-drab silty clay. White flecks of calcium carbonate are abundant.

Below a depth of 12 to 14 inches some areas have a layer of hard brittle structure rather than a friable condition. In some places car-

bonates are abundant throughout the surface layer as well as below a depth of 8 to 10 inches. A few small areas of Patent silt loam have been included on the map with Patent clay loam.

About 85 percent of Patent clay loam is tilled. It is used largely for the production of small grains with wheat occupying about 55 percent of the total acreage. The rest is used for barley, oats, flax, hay, and to a small extent for corn. It is considered a fairly productive soil, and as cropland it has a value of about 80 percent of that of Morton loam. In average good years wheat yields 10 to 14 bushels an acre, corn 15 to 20 bushels, and millet from 1 to 2 tons. In general, Patent clay loam is considered to furnish very good grazing, as the areas occupied by native grasses have a carrying capacity equal to or slightly greater than that of Morton loam.

When moisture conditions permit, Patent clay loam benefits some from fall plowing, but not so much as do the clay soils that are low in content of carbonates to a depth of 16 to 18 inches. The Patent soils, like the Grail soils, could be benefited by a system of terraces constructed to retain the excess surface water in those areas so located as to receive runoff from the immediate surrounding upland in not too great a volume.

Patent clay loam, slope phase.—This soil resembles Patent clay loam except that it lies on steeper slopes (7 to 15 percent) and has a more variable profile in respect to the depth, texture, and structure of the several layers. Small areas of Bainville loam and clay loam are included where the areas are too small and intimately associated with each other to warrant their separation on the published map. Drainage is good to excessive. The areas occur in association with other members of the Patent soils and generally occupy the area intermediate between the Bainville soils on the one side and the smoother lying Patent clay loam farther down the slope on the other side. The total area of 3.8 square miles occurs chiefly in the western part of the county.

The native vegetation is similar to that on Patent clay loam, but there is a greater proportion of blue grama. The stand is thinner, and there are some less desirable grasses such as little bluestem and three-awn.

The profile features are similar to those of Patent clay loam (page 73) except for a greater variation in the depth of the soil above the zone of calcium carbonate accumulation, the distinctness of the prismatic structure, and the texture of the underlying layers. A few areas with a silt loam rather than a clay loam surface layer have been included.

About 50 percent of Patent clay loam, slope phase, is tilled. Approximately the same crops are grown and the same methods of tillage are followed as on Patent clay loam. The steeper slope makes the operation of heavy farm machinery more difficult, and the hazard of soil loss by runoff is increased. Crop yields average from 15 to 25 percent lower than on the typical soil. The more sloping areas are better suited to grazing than to tillage, but the best use of these areas depends on the associated soils and the many other factors that determine the best management of a given farm. There has been some tendency in recent years to return more and more of these sloping areas to grass, but a satisfactory range is not immediately available

on the formerly cultivated fields. On account of steeper slope, these areas are drier than areas of Patent clay loam, and western wheatgrass does not establish itself so rapidly as on the more gentle slopes. The average carrying capacity of an undisturbed area is from 60 to 70 percent of that of Morton loam.

Patent clay loam, eroded phase.—This soil includes areas of Patent clay loam that have been badly eroded by runoff from the adjoining uplands. The areas have been subject to sheet erosion and scouring, or they have been cut severely by numerous ditches. These ditches vary from shallow channels a few inches deep and 2 to 8 feet wide to straight-sided channels 2 to 3 feet deep and 2 to 4 feet wide. The areas are gently to moderately sloping except for the gullies and a series of irregular steps that have been formed in places across the face of the slopes by the alternate removal and deposition of material by sheet wash. Surface drainage on the stabilized areas between the gullies is not excessive, as most of the runoff comes from the adjoining uplands. Internal drainage, however, is comparatively slow through the underlying heavy clay layers.

The native vegetation is predominantly blue grama, but the stand is markedly poorer than on the typical soil. Western wheatgrass grows on the slightly finer textured areas, and some niggerwood is on the slightly coarser textured areas.

The total area is 4.1 square miles. The most extensive area is south and southwest of Glen Ullin.

In general, Patent clay loam, eroded phase, is a less well-developed soil than Patent clay loam. In most places the surface layer is more gray and lacks the friable condition and the prismatic structure that breaks down to a crumb structure. In many places the surface material is dark-gray silt and clay that retains the laminated structure developed at the time the material was deposited. Below a depth of about 7 inches occurs a fairly hard olive-gray clay or sandy clay that is difficult to dig from place but the fragments of which crush easily.

None of the areas of Patent clay loam, eroded phase, are suited for tillage. The carrying capacity varies considerably from area to area. It is estimated that it averages about 15 percent of that of Morton loam.

Patent clay.—This soil represents areas of bare freshly deposited gray silt and clay alluvium formed at heads of drainageways or on gentle slopes immediately below upland areas from which the material has been washed. Many of the areas lie as gentle deltas at the base of bare buttes. At their lower edge a definite channel generally cuts through the adjoining land to form an outlet for runoff.

The total area is 0.3 square mile. The individual areas are small and are widely scattered. Their surface is nearly level or very gently sloping. This soil is almost devoid of vegetation. It is of no value for crop production and of very little value for grazing. Areas occasionally include small grassed patches of other soils.

Patent loamy fine sand.¹⁴—This sandy soil occurs on the broad gentle valley slopes below the breaks along the Cannonball River in

¹⁴ Patent loamy fine sand, as described here, involves a somewhat wider definition of the Patent series than is commonly given. The sandy character of the soil and the slight claypan are not typical, but these differences scarcely seemed to justify the establishment of a new series for these areas in Morton County.

the vicinity of Timmer and Breien. It is developed from the sandy local alluvial-colluvial material that has been washed from the sandy uplands, which are underlain principally by the Fox Hills sandstone. The soil exhibits a slight claypan or hardpan at a depth of about 2 feet. The lay of the land ranges from nearly level to gently sloping. Internal drainage is excessive because of the sandy porous nature of the subsoil. There is, therefore, very little runoff, if any, on these areas. The runoff that occurs comes from the uplands in the background. The areas of Patent loamy fine sand occur in association with areas of Patent-Moline fine sandy loams, Moline-Patent fine sandy loams, Flasher loamy fine sand, smooth phase, and Flasher loamy fine sand. The Flasher soil occurs as small knobs or knolls. The total area of Patent loamy fine sand is 5.5 square miles, and most of it lies within 5 miles of Breien.

The native vegetation is largely blue grama intermixed with patches of sandgrass. In places niggerwood is abundant, but it is less common than on Flasher loamy fine sand.

A generalized profile of Patent loamy fine sand is as follows:

- 0 to 10 inches, grayish-brown loamy fine sand that comes from place as slightly brittle irregular lumps
- 10 to 25 inches, light grayish-brown loamy fine sand. The material in this layer gradually becomes lighter in color and more sandy in texture with depth.
- 25 to 27 inches, moderately dense and hard dark olive-gray loamy fine sand that breaks to fragments only under considerable pressure.
- 27 to 30 inches, moderately dense and hard olive-gray loamy fine sand that is streaked with the dark olive-gray color of the immediate layer above.
- 30 inches +, calcareous olive-gray fine sand that is either loose or in brittle beds or laminations. This layer effervesces when treated with an acid, and in places calcium carbonate is readily observed as white flecks

The depth of the claypan (the two layers from 25 to 30 inches) varies somewhat between 20 and 30 inches, but the claypan is commonly 4 inches thick as indicated.

About 45 percent of Patent loamy fine sand is tilled, and the greater part of it is used for growing feed crops, such as corn, millet, barley, and oats, although some wheat is also raised. Inherent fertility is low, the water-holding capacity is very limited, and the soil is markedly subject to blowing when tilled. As a result, crop failures have been frequent and yields are irregular, averaging about the same as those obtained on Flasher loamy fine sand, smooth phase. In the interest of the best land use over a comparatively long period, it appears that this soil should be kept under a permanent grass cover and used for grazing rather than for tilled crops. The carrying capacity of this soil is estimated to average about 40 percent of that of Morton loam.

DARK GRAYISH-BROWN SOILS WITH CLAYPAN (SOLODIZED-SOLONETZ) AREAS

The dark grayish-brown soils with claypan (solodized-Solonetz) areas of the depressions and lower (concave) slopes consist of areas of Grail soils in which occur smaller areas or spots of Moline soils. The Grail-Moline complexes are comparable to the Morton-Rhoades and Bainville-Rhoades complexes in that the areas are characterized by the scattered distribution of claypan (Moline) soil and scab spots. These soil complexes differ from the Morton-Rhoades and Bainville-

Rhoades complexes in that they occur on the valley slopes instead of on the uplands, and that the parent materials are local alluvial-colluvial material from the uplands rather than the residual material of the uplands.

Grail-Moline silty clay loams.—This complex represents areas of Grail silty clay loam in which smaller areas of Moline silty clay loam are moderately distributed. The areas of the Moline soil are characterized by a claypan and associated so-called scab spots. Neither the density and thickness of the claypan nor the number of scab spots interfere sufficiently with the growth and tillage of crops to keep the areas out of cultivation. The surface is very gently to gently sloping, and most of the areas lie as smooth valley slopes immediately below higher lying uplands. As with the other soils of the Grail series, the parent material is clayey local alluvium-colluvium that has been washed from the adjoining uplands. Drainage, particularly internal, is slow. It is sufficient, however, to maintain a generally well-drained condition except for the periods immediately following heavy precipitation and during the early spring following the melting of snow. Although tillage during such periods cannot be practiced, drainage conditions are apparently satisfactory for plant growth. This complex is more extensive than Grail silty clay loam and has a total area of 79 square miles. The greatest acreage occurs in the vicinity of New Salem in association with the other Grail soils and the Williams and Morton soils.

The native vegetation on the areas between the scab spots is mostly blue grama with a variable amount of western wheatgrass and some prairie junegrass and western needlegrass intermixed. The grassed-over scab spots have a fair to good grass cover of blue grama or buffalo grass. A scant stand of western wheatgrass, saltgrass, small pricklypear, and gumweed occupies the more nearly bare scab spots.

A description of Grail silty clay loam that occupies a part of the area between the scab spots is given on page 70. A generalized profile of the Moline silty clay loam in the interspot area is as follows:

- 0 to 6 inches, dark grayish-brown to very dark grayish-brown friable silty clay loam. There is an abrupt change to the next layer.
- 6 to 12 inches, very dark grayish-brown (nearly black when moist) clay, which is hard and dense when dry. It comes from place when dry as hard sharply angular pieces $\frac{1}{4}$ to 1 inch in diameter. When wet the material is plastic and slick. Roots evidently penetrate this claypan layer with considerable difficulty, as they follow the vertical cracks
- 12 to 18 inches, the color grades to a lighter grayish brown, and the consistence becomes less hard with depth. When tested with acid, effervescence takes place at 1 to 3 inches below the claypan layer.
- 18 inches +, dark olive-drab silty clay with numerous white flecks of calcium carbonate. The mass breaks easily to small angular fragments that can be crushed with slight pressure.

The scab spots are irregular rounded patches 3 to 15 feet in diameter and about 6 inches lower than the surrounding surface. They occupy approximately 20 percent of the area and give to the landscape a moderately pitted or pock-marked appearance. The profile features are as follows:

- 0 to $1\frac{1}{4}$ inches, grayish-brown to dark grayish-brown fairly friable silty clay loam.

- 1½ to 4 inches, very dark grayish-brown fairly hard dense clay, resembling the claypan layer described above for the interspot area. The layer is not so thick, however, and the pronounced columnar structure is absent.
- 4 to 6 or 8 inches, transitional to olive-drab silty clay.
- 6 to 8 inches +, olive-drab silty clay with an abundance of white flecks of calcium carbonate. The material is hard in place but crushes easily when subjected to firm pressure.

Some of the scab spots that appear to be younger than the one just described have a gray siliceous crust of very fine sand from ¼ to ½ inch thick on the surface. Below this the material grades within another half inch to the hard, dense, and very dark grayish-brown clay.

About 85 percent of Grail-Moline silty clay loams is tilled. Small grains, particularly wheat, are the most commonly grown crops. Wheat occupies at least 55 percent of the total acreage. Oats, barley, hay crops, and corn are the other crops in the order of their acreage. The relative acreage of corn is less than on the soils with more friable subsoils, such as the Williams, Morton, and Arnegard soils. Most of the crops do well on the areas between the scab spots, but almost invariably they do poorly on the scab spots. In average good years the yield of wheat is about 13 bushels an acre, and of corn about 22 bushels.

The scab spots are sticky when wet and hard when dry, and consequently they are difficult to till in either wet or dry periods. Moreover, it is very difficult for plants to develop extensive root systems or to obtain sufficient moisture during the dry periods, as the clay particles of the soil hold a high percentage of the soil moisture tightly and make it unavailable to plants, with the result that the plants wilt, even if a comparatively high content of moisture is present in the soil. Farmers have found that continuous tillage over a period of years improves the tilth of the scab spots by breaking down the claypan condition and by mixing the more friable surface soil of the interspot areas with the soil of the scab spot. If moisture conditions allow, fall plowing is generally beneficial, since freezing and thawing during the winter and early spring aid in the granulation of the soil and make the preparation of a good seedbed less difficult in the spring.

The virgin areas of Grail-Moline silty clay loams provide good grazing. The carrying capacity is about 85 to 90 percent of that of Morton loam.

Grail-Moline silty clay loams, slope phases.—This complex consists of areas of Grail silty clay loam, slope phase, in which are scattered smaller areas of Moline silty clay loam, slope phase. Except for the steeper slopes (7 to 15 percent) and a somewhat more variable soil profile from place to place, these areas are similar to those of the Grail-Moline silty clay loams complex. They may also be compared to areas of Grail silty clay loam, slope phase, from which they differ in having areas of claypan and scab spots. A few small knobs of Bainville clay loam have been included in some areas, because of the impracticability of showing them separately on the soil map. Surface drainage is good to somewhat excessive, and internal drainage is slightly retarded on the Grail areas and definitely so on the Moline areas. A few areas have glacial boulders scattered on and through the soil. Where the stones are numerous enough to interfere with tillage they have been indicated on the soil map by symbols. This

complex occurs principally in the vicinity of New Salem in association with areas of the Grail, Williams, Morton, Patent, and Bainville soils. The total area is 3.5 square miles.

The native vegetation is essentially the same as that on Grail-Moline silty clay loams except for a slightly smaller relative proportion of western wheatgrass and blue grama in the interspot areas and more western needlegrass and little bluestem.

The profile features of the interspot and scab spot areas are essentially those given for Grail-Moline silty clay loams (page 77). More variation exists, however, from place to place in respect to (1) the thickness of upper layers above the zone of calcium carbonate accumulation, (2) distinctness of prismatic structure, and (3) the textures of the underlying layers.

From one-half to three-fourths of the total acreage is tilled. About the same crops are grown as on Grail silty clay loam and Grail-Moline silty clay loams. Yields average 15 to 25 percent less than they do on Grail silty clay loam and are somewhat less than those on Grail silty clay loam, slope phase. General farming practices and methods of tillage are about the same as on Grail-Moline silty clay loams except for the somewhat greater proportion of the areas that are left in grazing or cut for wild hay. The greater slope makes the operation of machinery more difficult and calls for more care in management.

The grazing value of Grail-Moline silty clay loams, slope phases, is 65 to 75 percent of that of Morton loam.

Grail-Moline silt loams.—This complex represents areas of Grail silt loam in which smaller areas of Moline silt loam are moderately distributed. The areas are similar in occurrence, appearance, and character to those of Grail-Moline silty clay loams. The significant differences relate to texture. Neither the density and thickness of the claypan nor the number of scab spots interfere sufficiently with the growth and tillage of crops to keep the areas out of cultivation. The surface is gently sloping, and the areas lie as smooth valley slopes below the higher lying uplands. Drainage is fair to good except that the internal drainage of the Moline areas is slow.

This soil complex has been developed on wash from the medium and lighter textured soils of the uplands, such as Morton loam, Bainville loam, and Flasher fine sandy loam. The underlying layers are heavy, because the silty deposits have been laid over the heavy clays that were exposed on the lower slopes by past geologic erosion. Seepage from the slopes above, nearness to the underlying heavy clays, and imperfect drainage are probably the principal factors that have led to the development of the areas of Moline silt loam.

The total area of Grail-Moline silt loams is 2.9 square miles.

The native vegetation is a mixture of blue grama, western wheatgrass, prairie junegrass, western needlegrass, and little bluestem on the interspot areas. The stand on the scab spots varies from a fair to good cover of blue grama and buffalo grass to a scant cover of western wheatgrass, saltgrass, small pricklypear, and gumweed.

The profile features of the interspot areas are essentially those of Grail silt loam (page 71), and those of the claypan areas and scab spots are similar to those of Moline silty clay loam (page 77).

Grail-Moline silt loams complex is used for the same crops as Grail silt loam or Grail-Moline silty clay loams. Yields are equal to or

slightly greater than on the heavier textured complex. Because of the silt loam texture, the moisture relations are slightly more favorable for crop growth and tillage is easier. The grazing value is about the same as for Grail-Moline silty clay loams.

BROWNISH-GRAY SOILS WITH CLAYPAN (SOLODIZED-SOLONETZ) AREAS

The brownish-gray soils with claypan (solodized-Solonetz) areas of the depressions and lower (concave) slopes consist of the soil complexes formed by the occurrence of scab spots and claypan soils in areas of Patent soils. The Patent-Moline complexes are somewhat similar to the Grail-Moline complexes except for the differences between the Patent and Grail soils of these complexes.

Patent-Moline clay loams.—This complex represents areas of Patent clay loam in which scab spots and areas of claypan are moderately distributed. The areas are similar to the Patent and Grail soils in position and topography and in origin of the parent materials. Except for the differences between the Grail and Patent series (principally color of surface soil, depth to the lime zone, and degree of development of prismatic structure), this complex is similar to Grail-Moline silty clay loams. The soil material is lighter colored, the depth to the lime zone is less, and the prismatic structure is less well developed in the Patent-Moline clay loams complex. The slope of the land is from 2 to 7 percent. Surface drainage is adequate, but internal drainage is slow, particularly on the areas of the Moline soil.

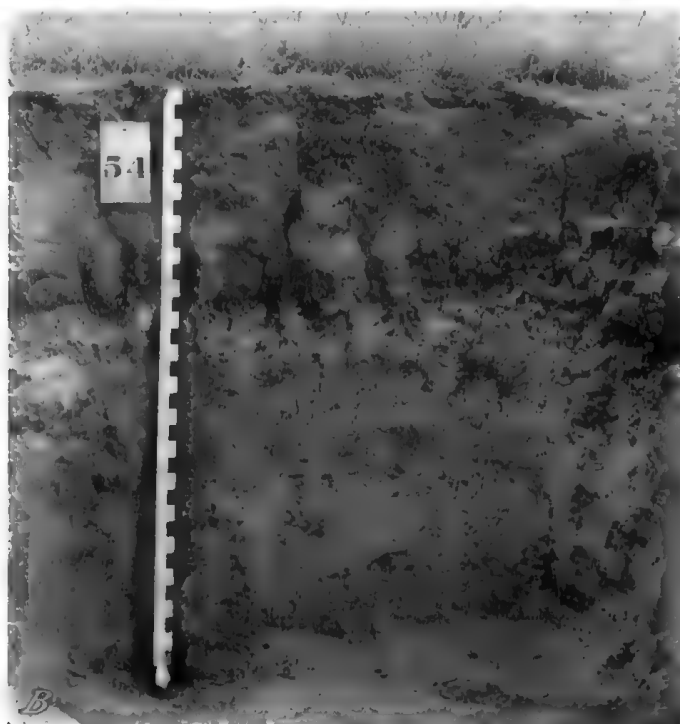
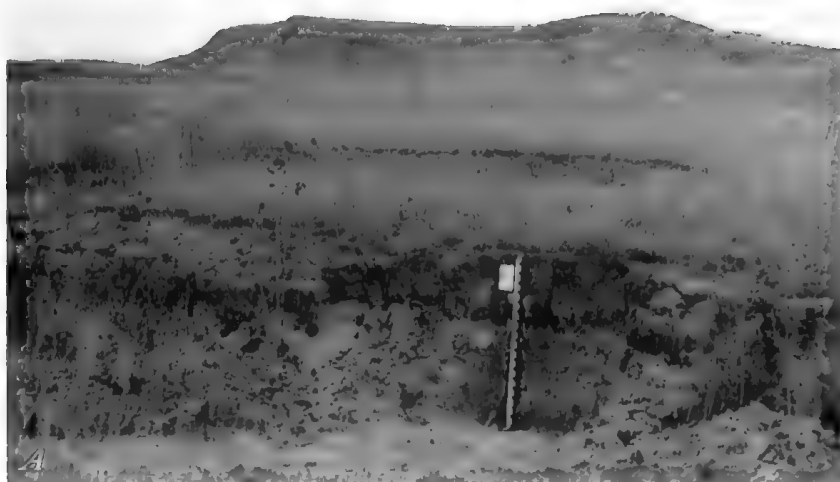
Patent-Moline clay loams is one of the most extensive of the soil complexes with claypan areas and scab spots. The total area is 86.4 square miles. Nearly all of the areas are west of New Salem, and the most extensive ones are south of Hebron. Patent clay loam and the Bainville soils are associated with this complex.

The native vegetation on the main, or interspot, areas is predominantly blue grama with some western wheatgrass and needlegrass intermixed. The vegetation on the scab spots varies. A few of them are unproductive and support only a scant growth of such plants as pricklypear, gumweed, and saltgrass. Many of them, however, are occupied by a fair or patchy cover of buffalo grass and western wheatgrass, and a few spots are completely occupied by buffalo grass intermixed to some extent with western wheatgrass and blue grama.

A generalized profile of Moline clay loam (pl. 10) in an interspot area is as follows:

- 0 to 6 inches, dark-gray to dark grayish-brown friable clay loam. There is an abrupt contact with the layer below.
- 6 to 12 inches, dark grayish-brown clay, which when wet is hard, dense, plastic, and slick. When dry it comes from place as hard sharply angular pieces $\frac{1}{4}$ to 1 inch in diameter. Roots evidently penetrate this claypan layer with considerable difficulty, as they follow the vertical cracks for the most part.
- 12 to 18 inches, the color grades to a light grayish brown, and the consistence becomes less hard with depth. When tested with acid, effervescence takes place at a depth of 1 to 3 inches below the claypan layer.
- 18 inches +, dark olive-drab silty clay with numerous white flecks of calcium carbonate. The mass breaks easily into small angular fragments that can be crushed with slight pressure.

The scab spots are irregular rounded patches from 3 to 15 feet in diameter and lie about 6 inches lower than the surrounding surface.



A, Profile of Moline clay loam and a landscape of Patent-Moline clay loams complex, with Bainville clay loam, steep phase, and Rough broken land in the background. **B**, Close view of the profile of Moline clay loam shown in **A**.

They occupy approximately 20 percent of the area and give to the landscape a moderately pitted or pock-marked appearance. Except for a lighter gray color, the profile features are similar to those of the scab spots of the Grail-Moline complex (page 77).

Approximately 85 percent of Patent-Moline loams is cropped. The same crops are grown as on Grail-Moline silty clay loams. Methods of farming and soil management are similar to those practiced on Grail-Moline silty clay loams, but the lower content of organic matter, the slightly lower water-holding capacity, and the somewhat less favorable tilth make the yields considerably less. In the average good years wheat yields about 11 bushels and corn about 16 bushels an acre.

The carrying capacity of the unplowed range land is from 80 to 85 percent of that of Morton loam.

Patent-Moline clay loams, slope phases.—This complex consists of areas of Patent clay loam, slope phase, in which are scattered smaller areas of Moline clay loam, slope phase. These areas are similar to those of the Patent-Moline clay loams except for the steeper slopes and a somewhat more variable soil profile. They are also similar to areas of Patent clay loam, slope phase, except in the presence of the included areas of claypan and scab spots. A few small areas of Bainville clay loam are included where they are too small to show separately on the soil map. Surface drainage is somewhat excessive, and internal drainage of the Moline spots is slow. The areas of this complex occur in association with other members of the Patent soils and commonly occupy the area intermediate between the Bainville soils on the one side and the smoother lying Patent-Moline clay loams farther down the slope on the other side. A total area of 3.5 square miles is mapped, chiefly in the western part of the county.

The native vegetation is similar to that on Patent clay loam, slope phase, except for the patches of saltgrass, small pricklypear, and gumweed associated with the scab spots.

The profile features of Patent clay loam, slope phase, are given on page 74, those of the Moline clay loam claypan spots on page 80, those of the scab spots of the Grail-Moline complex on page 77.

About 50 percent of Patent-Moline clay loams, slope phases, is tilled. Approximately the same crops are grown and the same methods of tillage are followed as on Patent clay loam, slope phase, except that very little corn is grown. Owing to the greater slope, the operation of machinery is difficult, and the hazard of soil loss by both runoff and blowing is increased over that on areas of Patent-Moline clay loams. Crop yields are somewhat less than on Patent clay loam, slope phase, because of the included scab spots. These areas, particularly the more sloping ones, are better suited to grazing than to tillage. There has been a tendency to return the more sloping and scabby areas to grass, but a satisfactory range is not immediately available on formerly cultivated fields. The average carrying capacity of an undisturbed area is from 60 to 70 percent of that of Morton loam.

Patent-Moline silt loams.—This soil complex represents areas of Patent silt loam in which scab spots and areas of claypan are moderately distributed. These areas are similar to those of the Patent-Moline clay loams complex except that the texture is not so heavy. The slope of the land is from 2 to 7 percent. Surface drainage is

good, and internal drainage is slow, particularly on the Moline areas.

Patent-Moline silt loams complex is one of the least extensive of any of the complexes or soil types mapped in Morton County. Its total area is 5.2 square miles. It is associated with the other Patent-Moline complexes, chiefly in the western part of the county.

The native vegetation, like that on the Patent-Moline clay loams, is predominantly blue grama with some western wheatgrass and needlegrass on the interspot areas, and the vegetation of the scab spots is more variable. Most of these areas have a fair cover of buffalo grass and western wheatgrass, whereas others are less productive and support such plants as pricklypear, gumweed, and saltgrass.

A generalized profile of Patent silt loam shows the following layers:

- 0 to 6 inches, brownish-gray or dark-gray friable silt loam to very fine sandy loam.
- 6 to 10 inches, brownish-gray to gray heavy silt loam to clay loam. The material is friable and crumbles easily to a fine-grained mass. There is some evidence of prismatic structure.
- 10 to 18 inches, gray or olive-gray friable clay loam. Generally calcareous.
- 18 inches +, laminated olive-gray clay or silt. White flecks of calcium carbonate are present.

Except for the smaller content of clay in the surface, the profile features of the Moline member of this complex are similar to those of Moline clay loam (page 80).

About 50 percent of Patent-Moline silt loams is tilled. Approximately the same proportion of wheat, oats, barley, corn, and millet are grown as on Patent-Moline clay loams except for a slightly higher proportion of corn and millet. The same general methods of farming are followed, although tillage is less difficult and yields are slightly higher.

The carrying capacity of unplowed pasture land is comparable to that of Patent-Moline clay loams and is about 80 to 85 percent of that of Morton loam.

Patent-Moline fine sandy loams.—This soil complex contains more sand than any of the other claypan complexes. It occurs on the gentle slopes of the Cannonball River valley and has developed from local sandy clay alluvium that has been washed from the adjoining uplands. The lay of the land is similar to that of Patent loamy fine sand. It differs in the presence of scab spots and in having a shallower depth to the claypan and to the zone of carbonates. Surface drainage is good, but internal drainage is slow. Under average conditions, however, it is entirely satisfactory for crop growth. The total area of 9.7 square miles lies almost entirely north, northeast, and northwest of Breien.

The native vegetation on the areas between the scab spots is principally blue grama. There is some niggerwool, but it is not so abundant as on Flasher fine sandy loam and loamy fine sand.

The profile features of the Patent parts of the interspot areas are similar to those of Patent loamy fine sand except that the surface layers have slightly finer textures (page 76). The general profile features of Moline fine sandy loam are as follows:

- 0 to 6 inches, grayish-brown fine sandy loam to loamy fine sand.
- 6 to 12 inches, hard and dense dark olive-brown sandy clay or sandy clay loam.

- 12 to 16 inches, olive-brown friable sandy clay loam, generally with numerous white flecks of calcium carbonate distributed through it, but in some places no marked effervescence takes place when tested with acid.
- 16 inches +, olive-drab or olive-gray sandy clay loam with numerous white flecks of calcium carbonate.

A few areas are underlain by olive-gray loamy fine sand instead of olive-gray sandy clay loam. Small areas of Flasher loamy fine sand that were too small to show separately have been included in some of the larger areas.

About 40 percent of Patent-Moline fine sandy loams is tilled. Although some wheat is grown, feed crops, such as corn, oats, and barley for both forage and grain, are the most common crops. Yields are low and irregular from year to year and are about the same as those obtained on Flasher loamy fine sand, smooth phase. The soil is difficult to manage, as it is low in fertility and moisture-holding capacity and is subject to severe blowing. This soil is best suited for grazing even though a large part of it is cropped. The carrying capacity of virgin areas is about 40 percent of that of Morton loam.

***DARK GRAYISH-BROWN SOILS WITH NUMEROUS CLAYPAN (SOLODIZED-SOLONETZ) AREAS**

The dark grayish-brown soils with numerous claypan (solodized-Solonetz) areas of the depressions and lower (concave) slopes differ from the dark grayish-brown soils with claypan (solodized-Solonetz) areas principally in the greater number of scab spots and in the larger proportion of the total area underlain by claypan. The scab spots occupy 25 to 70 percent of the total area, and the claypan probably covers 50 to 90 percent of the interspot areas. Because of the numerous scab spots and the claypan underlying the larger part of the interspot areas, the soils of this group are not considered suitable for tilled crops. The interspot areas, however, carry a desirable grass cover for grazing, and although the carrying capacity is comparatively low, the total acreage provides considerable pasture or range.

Moline-Grail silty clay loams.—This soil complex consists of areas of Grail silty clay loam in which are numerous scab spots and in which a claypan has developed in a relatively large proportion of the interspot areas. The irregular rounded scab spots give the landscape a pock-marked appearance and range from 2 to more than 15 feet in diameter. Owing to the number of scab spots and the compactness and thickness of the claypan in the interspot areas, these areas are not suited for tillage.

The slope of the land is from 2 to 7 percent. Surface drainage is good, but internal drainage is slow because of the impervious character of the claypan and underlying clay material. This complex has a total area of 11.5 square miles. Most of the areas are associated with Grail silty clay loam and occur to the north and east of New Salem.

The native vegetation of the interspot areas is dominantly blue grama with some western wheatgrass and prairie junegrass intermixed. Many of the scab spots are bare or nearly bare. The vegetation on the others is commonly a sparse growth of saltgrass, western wheatgrass, small pricklypear, and annual weeds.

The soil conditions in this type of soil complex vary within short distances. The profiles range from those of Moline silty clay loam with a maximum of claypan development, through Moline soils with less distinct claypan, to Grail soils free of claypan. A generalized profile description of Grail silty clay loam is given on page 70, of Moline silty clay loam in the interspot area on page 77, and of the scab spots of Moline silty clay loam on page 77.

Moline-Grail silty clay loams complex is best suited for grazing and should be left in the virgin condition, although attempts have been made to farm a few small areas. The carrying capacity is about 45 percent of that of Morton loam.

BROWNISH-GRAY SOILS WITH NUMEROUS CLAYPAN (SOLODIZED-SOLONETZ) AREAS

The brownish-gray soils with numerous claypan (solodized-Solonetz) areas of the depressions and lower (concave) slopes differ from the brownish-gray soils with claypan (solodized-Solonetz) areas in the greater number of scab spots and in the larger proportion of the total area underlain by claypan. The scab spots occupy 25 to 70 percent of the total area, and the claypan probably covers 50 to 90 percent or more of the interspot areas. As is true of the other complexes with numerous claypan (solodized-Solonetz) areas, these Moline-Patent areas are not considered suitable for tilled crops.

Moline-Patent clay loams.—This soil complex consists of areas of Patent clay loam in which are numerous scab spots and in which a claypan has developed in a relatively large part of the interspot areas. The irregularly rounded scab spots range from 2 to more than 15 feet in diameter and give the landscape a pock-marked appearance. They lie about 7 inches below the level of the general surface of the remaining soil and occupy 25 to 70 percent of the total area. The complex is commonly referred to as gray gumbo land.

The slope of the land is from 2 to 7 percent. Surface drainage is good, but internal drainage is slow because of the imperviousness of the claypan and underlying clay materials. Moline-Patent clay loams occupy 51.1 square miles, most of which is associated with Patent clay loam in the western part of the county.

The native vegetation on the areas between the scab spots is predominantly blue grama with some western wheatgrass, western needlegrass, prairie junegrass, and other such grasses intermixed. Little clubmoss is common and in places occupies a considerable part of the land. Other vegetation includes saltgrass, prairie plantain, pasture sagebrush, gray sagebrush, and pricklypear. Many of the scab spots are bare or nearly so. The most common vegetation on them, where it is at all established, consists of a sparse growth of saltgrass, western wheatgrass, weeds, and small pricklypear. Saltgrass and small pricklypear are the most persistent plants. During the wetter or moist years western wheatgrass makes a very noticeable growth. Some of the scab spots have a cover of buffalo grass or blue grama.

A generalized profile description of Patent clay loam is given on page 73.

A generalized description of Moline clay loam in the areas between the scab spots is as follows:

- 0 to 6 inches, grayish-brown friable silt loam.
- 6 to 12 inches, dark olive-brown to nearly black dense clay, which when dry comes from place in hard, sharply angular or blocky pieces $\frac{1}{4}$ to 1 inch in diameter. When wet the clay is plastic and slick. Roots penetrate this layer with considerable difficulty, and the greater part of them follow the vertical cracks.
- 12 to 18 inches, color grades to a lighter grayish brown and the consistence becomes less hard with depth. This layer is generally calcareous within 1 to 3 inches of the surface.
- 18 inches +, olive-drab clay or silty clay with numerous white flecks of calcium carbonate. The mass breaks easily into small angular fragments that can be crushed with slight pressure.

A generalized profile description of a scab spot of Moline clay loam is as follows:

- 0 to $\frac{1}{4}$ inch, a brittle crust of olive-gray silt or very fine sand that breaks with brittleness to a powdery mass.
- $\frac{1}{4}$ to 3 inches, very dark to brownish-gray hard, dense clay. This layer resembles the claypan layer at a depth of 6 to 12 inches in the interspot areas, but it is thinner, does not have vertical cracks, and does not break easily into hard angular fragments.
- 3 to 7 inches, this layer is transitional to the olive-drab clay of the layer below.
- 7 inches +, olive-drab silty clay that is hard in place but crushes fairly easily when subjected to firm pressure.

Moline-Patent clay loams complex is best suited to grazing, because of the comparatively good quality of the grass (blue grama) on the areas between the scab spots. Very little of this soil is or has been cropped, because of the low productivity and difficult workability of the claypan areas and scab spots. The carrying capacity as range land is about 40 percent of that of Morton loam.

Moline-Patent clay loams, slope phases.—This complex consists of areas of Patent clay loam, slope phase, in which there are numerous scab spots and in which the claypan covers a relatively large part of the area between the scab spots. The slope of the land is from 7 to 15 percent. The areas are similar to those of Moline-Patent clay loams except that they have a greater slope. Surface drainage is good to excessive, and internal drainage is slow because of the impervious claypan and underlying clay materials. The total area of 5 square miles occurs chiefly in the western part of the county in association with other Patent soils.

The native vegetation is similar to that on Patent clay loam, slope phase, except for the patches of saltgrass, small pricklypear, and gumweed that are associated with the scab spots. It differs somewhat from the grass on Moline-Patent clay loams in having a smaller proportion of blue grama and a larger quantity of western needlegrass, prairie junegrass, little bluestem, and three-awn grass.

The profile characteristics are essentially those of Moline-Patent clay loams complex, but it differs in having greater variability in places and in having a few small areas of Bainville clay loam included.

This complex is considered to be range land and unsuited for tilled crops because of the difficult workability, low productivity, and hazard of water erosion. Prevention of overgrazing is the most needed measure of pasture management. The carrying capacity is about 35 percent of that of Morton loam.

Moline-Patent silt loams.—This complex consists of areas of Patent silt loam in which there are numerous scab spots and in which the claypan covers a relatively large part of the area between the scab spots. The slope of the land is from 2 to 7 percent. Surface drainage is good, but internal drainage is slow, particularly on the Moline areas. This complex is similar to Moline-Patent clay loams complex but differs in the texture of the surface soil. The differences are principally improved consistence or workability, more rapid infiltration of rain water, and a slightly more available supply of moisture, especially in the Patent areas of the complex. This complex is inextensive. The total area of 5 square miles is situated almost entirely in the western part of the county.

The native vegetation on the interspot areas is composed of the same grasses as on Moline-Patent clay loams and consists principally of blue grama with western wheatgrass, western needlegrass, and prairie junegrass intermixed. Little clubmoss is also common in places. Saltgrass, pasture sagebrush, pricklypear, gray sagebrush, and prairie plantain are present to some extent. Many of the scab spots are bare or nearly so. On others a sparse growth of saltgrass, western wheatgrass, small pricklypear, gumweed, and other weeds form the natural cover.

The profile features are those of the other Moline-Patent complexes. A discussion of Moline clay loam of the interspot areas is on page 84 and of the scab spots on page 85. A discussion of Patent silt loam is on page 82.

Moline-Patent silt loams complex, like Moline-Patent clay loams complex, is not considered suitable for cropland, because of the low productivity and difficult workability of the claypan areas and scab spots, although as a complex it is slightly less difficult to till than the clay loams. It should be left in range, and measures should be taken to prevent overgrazing. The carrying capacity is estimated to be the same as that of Moline-Patent clay loams and is about 40 percent of that of Morton loam.

Moline-Patent fine sandy loams.—This complex is comparable to Patent-Moline fine sandy loams complex except for the greater number of scab spots and the larger proportion of the total area underlain by claypan. The surface is nearly level or very gently sloping. Both surface drainage and internal drainage are slow to fair. Most of the areas occur at the foot of gentle fans or at the base of colluvial slopes where they merge with the valley floor of the Cannonball River. The total area of 9.4 square miles is practically all drained by the Cannonball River, and most of it is in the vicinity of Breien.

The vegetation on the areas between the scab spots is predominantly blue grama. Some niggerwool is present, but it is less common than on such soils as Flasher fine sandy loam and Flasher loamy fine sand. The scab spots are nearly bare. The sparse vegetation generally consists of isolated plants of saltgrass, a thin stand of blue grama, and some weeds.

A generalized profile of Moline fine sandy loam in the interspot areas is as follows:

0 to 5 inches, dark grayish-brown fine sandy loam. This comes from place as rather brittle but easily crushed fragments.

5 to 9 inches, hard dense dark-brown tinged with olive sandy clay or sandy clay loam. There is a very abrupt boundary between this layer and the one above.

9 to 16 inches, the color grades toward olive drab, and the hardness diminishes. This layer is commonly calcareous.

16 inches +, olive-drab sandy clay loam with an abundance of white flecks of calcium carbonate. The material is fairly hard in places but crushes under moderate pressure to a fine-grained mass.

A few areas are underlain by more sandy material, and in those places the texture of the claypan layer is coarser and approaches a sandy loam.

The profile features of the scab spots are similar to those of Moline clay loam of the scab spots (page 85) except that the texture of the claypan is more nearly a sandy clay loam than a clay.

Only a very small part of this soil has ever been tilled. Its low productivity and difficult workability make it suitable only for grazing. It is considered fair range land and has a carrying capacity of about 30 percent of that of Morton loam. Improved management of the range is needed on this as on the other soils best suited for grazing.

DARK-GRAY INTRACTABLE CLAYS

The dark-gray intractable clays of the depressions and lower (concave) slopes include only one soil type—McKenzie clay. This dense clay is similar in physical character to the dense claypans of the claypan soils, but it differs greatly in its uniform distribution and degree of development. The areas represent sites of former ponds, and the moisture condition varies from year to year, depending upon whether the season is a comparatively dry or wet one.

McKenzie clay.—This soil is the nearly black hard dense clay that occupies depressions in the uplands or on the low terraces of stream valleys. It is generally called black gumbo. The surface is nearly level or slightly saucerlike. Surface and internal drainage are very slow. Most of the areas are sites of former ponds, and during seasons of comparatively heavy precipitation they are either thoroughly waterlogged or are again ponded. The areas are generally small and scattered. The two largest ones are in secs. 22 and 23, T. 140 N., R. 89 W., and sec. 21, T. 135 N., R. 84 W. The total area is 5.5 square miles.

The vegetation varies from place to place, depending on the moisture condition. Likewise it varies from year to year and from season to season, depending on the quantity and distribution of rain. The areas that are permanently wet are occupied for the most part by lowland sedges and small reeds, whereas the drier, or outer, fringe of such areas is occupied by such vegetation as wild barley. Some of these wettest areas have a boggy or hummocky surface. The naturally less wet areas during moderately dry seasons support a sparse to fair growth of mixed western wheatgrass, saltgrass, and some annual weeds and herbs. These same areas may produce a rank growth of western wheatgrass or of weeds such as smartweed and wild sunflowers with some small reeds during moderately wet seasons. Excessively dry years result in practically no vegetative growth.

The following is a generalized description of the soil profile of McKenzie clay:

0 to 15 inches, very dark gray or nearly black clay. When dry the clay is hard and dense and comes from place in large hard angular to blocky chunks. In place the mass of clay is thoroughly cracked into blocks 1 to 3 feet in diameter. Under extremely dry conditions these cracks are $1\frac{1}{2}$ to 3 inches across and extend downward to where the soil is more moist. When thoroughly moistened the soil is plastic and tenacious. This layer varies in depth from 12 to 30 inches.

15 to 36 inches, the color gradually becomes lighter. This layer is generally calcareous throughout, and white flecks of calcium carbonate are generally easily observed at a depth of about 20 inches, although in a few places when tested with acid, effervescence has been observed within a few inches of the surface.

36 inches +, dark olive-drab calcareous clay.

Several variations have been included with McKenzie clay as it is shown on the soil map. There are a few areas that are not quite as dark throughout the surface layer as described above, although they have a hard dense consistence and are otherwise similar to the type. A few other areas in the less well-defined depressions have a somewhat more friable consistence in the 4- to 6-inch surface layer and are tilled with some success.

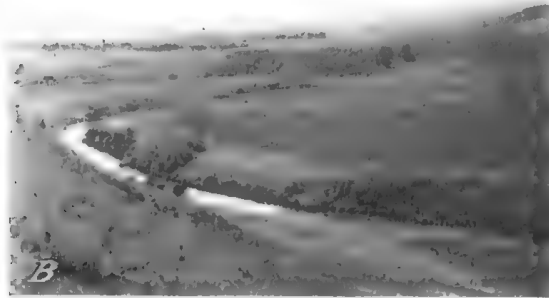
The most pronounced and extensive variation is that in which the 4- to 7-inch surface layer is gray silt loam. In place, the soil has a platy structure and numerous air pores or vesicles are plainly visible. The material comes from place in large lumps that are easily crushed to a powdery condition. When moist the surface soil has a noticeably darker color. Just below this layer the subsoil is very dark-gray or nearly black hard dense clay that is similar to the soil material at this depth in typical McKenzie clay. Flecks of calcium carbonate and salt crystals are seldom above a depth of 16 to 18 inches. The section on Morphology and Genesis of Soils contains a further discussion of the morphological significance of this variation of McKenzie clay.

Probably 50 percent of the total area of McKenzie clay is either left in virgin western wheatgrass meadow or is tilled. The tilled acreage probably occupies about 25 percent of the total acreage and naturally includes the parts more suitable for tillage. Wheat is the crop most commonly grown. Yields are variable and generally low because of the poor drainage and undesirable structure, consistence, and tilth. McKenzie clay is a difficult soil to till, although the included variation with the gray silt loam surface is more easily worked. These more friable and more productive areas are probably best used over a period of years as meadowland, since comparatively good yields of western wheatgrass of excellent quality can be obtained. The value of these better areas as meadow or tillable land is about 40 percent of that of Arnegard silt loam, and as grazing land, about 60 percent of that of Morton loam.

The poorer drained or wetter areas afford some grazing, but their usefulness varies considerably with the drainage and moisture conditions from year to year. Their value for grazing is about 10 percent of that of Morton loam.

GRAY POORLY DRAINED SOILS

The gray poorly drained soils of the depressions and lower (concave) slopes include only one soil type—Dimmick clay. This soil occupies depressions and old stream channels of the lowlands, prin-



A, View in the Heart River valley. The bottom lands, terraces, and alluvial fans offer satisfactory sites for ranch homes and for the growing of feed crops, such as the crop of oats shown here. B, Flood plains and terraces along Sweetbriar Creek, used principally for feed crops and pasture. Note the stream meanders in the flood plain and the depth of this valley below the general level of the uplands as measured by the hills in the background. C, Corn and alfalfa, important crops on cleared areas of Havre silty clay and Havre silt loam. Cottonwoods are in the background.

cipally in the Missouri River bottom lands, on which water usually stands for a part of the growing season. Most of the areas are nearly bare, and they have little value for grazing or other agricultural uses.

Dimmick clay.—The surface of this soil is nearly level or slightly depressed. Drainage is poor throughout. The total area is 0.7 square mile. Most of this soil occurs on the bottom lands along the Missouri River, although a few areas are located elsewhere in the county.

Dimmick clay is unsuited to tillage, and its grazing value is extremely low. Most of the areas are nearly bare, as vegetation is very scant. Smartweeds, lowland sedges, and rushes are common on the areas where some vegetative growth has been able to establish itself.

A generalized profile of Dimmick clay is as follows:

0 to 2 inches, gray clay, which when dry appears as dried mud with numerous surface cracks.

2 inches +, mottled gray and yellow clay. In places the clay is partly replaced by sandy material.

SOILS OF THE TERRACES, ALLUVIAL FANS, AND NATURAL LEVEES

The soils of the terraces, alluvial fans, and natural levees occupy the stream terraces, alluvial fans, and natural levees that have been formed along the principal streams of the county, such as the Missouri River, the Heart River (pl. 11, A), the Cannonball River, the Knife River, the Little Heart River, Sweetbriar Creek (pl. 11, B), Big Muddy Creek, Louse Creek, and Chanta Peta Creek. The terraces that represent old flood plains now lie from a few feet to 40 or 50 feet above the present bottom lands. The alluvial fans represent gently sloping deposits that have been deposited on the valley floors at the mouths of tributary drainageways, whereas the natural levees have been formed by deposits laid down along the banks of streams at times of overflow. All of the soils are characterized by relatively smooth relief and overlie more or less stratified material.

The Hall soils are developed from relatively fine-textured material in which moisture relations have been more favorable for vegetative growth, and the Cheyenne soils are developed over gravel and sands. The soils of the Cherry and Huff series do not exhibit distinct zonal characteristics, since they occur on the younger low terraces, alluvial fans, and natural levees that have been the scenes of more recent deposition. They are lighter in color, possess less definite soil structure, and are more variable in the depth to carbonates. The Wade soils are intrazonal and owe their characteristics to local conditions of impeded drainage.

VERY DARK TO DARK GRAYISH-BROWN SOILS OF THE TERRACES

The very dark to dark grayish-brown soils of the terraces include members of the Hall series. These soils, together with the Arnegard, Timmer, and Grail soils of the depressions and lower (concave) slopes, form the darkest, deepest, and most productive soils of Morton County.

Hall silt loam.—This soil is very dark grayish-brown friable silt loam on the terraces (second bottoms) of the river and larger stream valleys. The surface is generally gently undulating on the terraces of the larger streams, although it is undulating with a gentle though definite slope toward the river on the terraces along the Missouri River.

Internal drainage is good, and surface drainage is sufficient for good crop growth. The total area is 29.5 square miles. The most extensive areas are southeast of Saint Anthony, along Big Muddy Creek, along Square Butte Creek, and in the vicinity of Fort Rice. Most of the areas range from 30 to 200 acres, although a few occupy more than a square mile.

The native vegetation is mixed blue grama and western wheatgrass with some porcupine grass, western needlegrass, and prairie junegrass.

Hall silt loam has the following generalized profile characteristics:

- 0 to 5 inches, very dark grayish-brown friable loam.
- 5 to 18 inches, very dark grayish-brown silt loam that grades to dark grayish-brown silty clay loam. The structure is almost invariably prismatic. The elongated prisms break easily to nut-sized fragments when disturbed by a spade and are easily crushed to a crumbly mass with slight pressure.
- 18 to 24 inches, the soil becomes heavier and grayer with depth. Prismatic structure continues.
- 24 to 28 inches, dark olive-drab or olive-drab fairly friable silty clay, generally calcareous. The prismatic structure is less distinct in this layer.
- 28 inches +, olive-drab fairly friable silty clay with white flecks of calcium carbonate.

There are a few areas, especially in the valley of Big Muddy Creek, that grade from very dark grayish brown to dark grayish brown at a depth of about 8 inches. When tested with acid, effervescence takes place at a depth of less than 24 inches.

Approximately 90 percent of the area of Hall silt loam is tilled. Probably 60 percent of it is cropped to wheat, and the rest is about equally divided between barley, oats, corn, and hay and forage crops, such as small grains cut green, millet, sorghum, and sweetclover. Crop yields are comparatively high and average a little better than on Williams silt loam. During years in which black stem rust is prevalent, however, the wheat on areas of the Hall, Arnegard, and Timmer soils is more likely to suffer damage than that on the higher lying or more rolling areas of the Williams, Morton, or Bainville soils.

Because of its terrace position, smooth surface, good tilth, and naturally high state of fertility, Hall silt loam is one of the most desirable soils in the county. It is well suited to a wide range of crops and to a system of diversified farming that includes row crops, small grains, and hay crops. As cropland this soil is considered to have a value of about 95 percent of that of Arnegard silt loam. Virgin areas that are used as range land furnish very desirable grazing and have a carrying capacity equal to or slightly greater than that of Williams silt loam.

Hall loam.—This soil has a coarser texture, is somewhat lighter in color, and has a less uniformly developed prismatic structure in the upper 16 to 18 inches than Hall silt loam. The surface is undulating or gently sloping. Drainage is good throughout. The total area is about 13.6 square miles. The most extensive acreage is in the vicinity of Schmidt and Saint Anthony.

The native vegetation is similar to that on Hall silt loam, except that on the more sandy areas blue grama and niggerwool tend to dominate, rather than blue grama and western wheatgrass.

The following is a generalized profile description of Hall loam:

- 0 to 6 inches, dark grayish-brown to very dark grayish-brown loam to very fine sandy loam.
- 6 to 18 inches, dark grayish-brown loam with ill-defined prismatic structure that breaks down easily into nut-sized fragments. In some places the soil comes from place in irregular pieces instead of in the nut-sized fragments.
- 18 to 24 inches, the soil becomes heavier and grayer with depth. Prismatic structure becomes indistinct.
- 24 inches +, olive-drab sandy clay loam to silty clay. The soil is calcareous at a depth of about 24 inches, and white flecks of calcium carbonate are observable at about 26 inches. In some places the material is more sandy at this depth.

In the vicinity of Schmidt a considerable area of very fine sandy loam has been included and shown on the map as Hall loam. The surface soil of this area is about as dark as that of Hall silt loam. The areas of Hall loam north of Saint Anthony in general are lighter colored than Hall silt loam, and some fine sand and sand are mixed with the finer textured particles.

Probably 90 percent of Hall loam is tilled. It is used for the same crops as Hall silt loam, although the proportion of the area in corn appears to be somewhat higher, as this crop is better adapted to the sandier areas than are the small grains. Yields of wheat and other small grains are good, although the average yield is slightly less than on Hall silt loam. Forage crops, such as millet and sorghum, are well suited to this soil. Millet produces about 1½ tons an acre in average good years. The value of Hall loam for either cropland or grazing is nearly equal to that of Williams silt loam and is about 90 percent of that of Arnegard silt loam.

Hall silty clay loam.—This heavy dark-colored well-drained soil occupies the gently undulating or gently sloping terraces. Drainage is slow, although it is sufficient for good crop growth under normal conditions. The total area is 12 square miles. The principal areas are in the Missouri River valley between Mandan and Huff and in Big Muddy Creek valley in the vicinity of Glen Ullin.

The native vegetation consists of a mixture of blue grama and western wheatgrass. It affords good grazing, and if protected from grazing it generally makes excellent stands of wild hay.

The following is a generalized profile description of Hall silty clay loam:

- 0 to 5 inches, very dark grayish-brown fairly friable clay loam or silty clay loam.
- 5 to 15 inches, dark grayish-brown to very dark grayish-brown silty clay loam with moderately well-developed prismatic structure. The material comes from place in a more chunky condition and the fragments are harder than those of Hall silt loam.
- 15 to 20 inches, the color of the soil gradually becomes lighter with depth. This layer is commonly calcareous, as shown by effervescence when treated with acid, although there is some variation in the actual depth to free lime from place to place.
- 20 inches +, fairly friable olive-drab silty clay with numerous white flecks of calcium carbonate.

Small areas exhibit a claypan (solodized-Solonetz condition) at a depth of about 6 inches. Such soils are classified in the Wade series, but because of their small extent they have been indicated on the soil map by the scab-spot symbol. Where the claypan is more extensive, or where scab spots are more numerous, the areas are shown either as

Hall-Wade or Wade-Hall complexes, depending on the relative proportion of the areas so affected.

Probably 85 percent of Hall silty clay loam is tilled. Wheat, the principal crop, occupies about 65 percent of the total area. Most of the remaining tillable part is used for small grains and hay crops, which are well adapted to this soil, and the yields of these crops approximate those obtained on Hall silt loam. Only a small acreage of corn is grown. Flax does well except that weeds are difficult to control.

The silty clay loam texture and hard consistence of Hall silty clay loam make it comparatively difficult to plow and cultivate. Row crops, such as corn and potatoes, are not so well suited as the small grains, and the control of weeds is more difficult. If moisture conditions are such that fall plowing can be done, the tilth is generally improved by the alternate freezing and thawing of the late fall and early spring seasons. As cropland Hall silty clay loam is valued at about 85 percent of the valuation of Williams silt loam, and for grazing it is considered to be equal to or slightly better than Williams silt loam.

DARK GRAYISH-BROWN TO BROWN SOILS OF THE TERRACES

The dark grayish-brown to brown soils of the terraces include the Cheyenne series. These soils, like the Williams and Morton soils of the uplands, express rather completely the characteristics of the Chestnut zonal group of soils. The Cheyenne soils have a pronounced prismatic structure, are well drained, occupy relatively smooth areas, are easily tilled, are comparatively deep over underlying calcium carbonate, and have developed under a short-grass vegetation. These soils are similar to the Morton soils of the uplands, but they are more droughty because they are underlain by sand and gravel.

Cheyenne loam.—This dark grayish-brown soil is developed on the gravelly stream terraces or benches. The land generally is strongly undulating except for a few areas that have a gently rolling to almost bumpy surface. Surface drainage is good, but internal drainage is good to excessive. A few areas are excessively drained where the underlying gravel is within 10 to 12 inches of the surface. Most of the areas are on the high benches along the Missouri River south from Mandan to the vicinity of Schmidt. The total area is 0.5 square mile.

The native vegetation is predominantly blue grama with considerable niggerwool and western needlegrass intermixed. Niggerwool predominates on the more droughty areas, and in such places gumweed, skeletonweed, and purple coneflower are also common.

The following is a generalized profile description of Cheyenne loam :

- 0 to 5 inches, very dark grayish-brown loam that crumbles easily to a soft crumbly mass.
- 5 to 17 inches, dark grayish-brown loam or gritty clay loam with a fair to well-defined prismatic structure. The upper 3 inches of this layer are generally very dark grayish brown. The prisms break into nut-sized fragments that crush under firm pressure to a mealy or crumbly mass. The thickness of this layer varies from 14 to 22 inches.
- 17 to 23 inches, alluvial gravel coated by a white covering of calcium carbonate, particularly on the lower sides. Part of the gravel is granitic in origin.
- 23 inches +, alluvial gravel beds 1 to 15 feet thick, below which are clay beds of the Lance formation.

Where the gravel lies at a depth of more than 17 inches the soil material below is olive brown and contains an abundance of white flecks of calcium carbonate. Gravel is generally scattered throughout the soil to some degree, but not in sufficient quantity to interfere with tillage except in a few small patches where the surface soil layers are less than 10 to 12 inches thick. These areas are indicated by gravel symbols. Another variation included with Cheyenne loam is the gently rolling to bumpy areas in which the brown surface soil varies in depth from typical to deeper than typical in the depressions and is shallow and gravelly on the knolls. These areas are definitely poorer than the typical soil and are probably best used as grazing land.

Approximately 80 percent of Cheyenne loam is tilled. Wheat is the principal crop, but other small grains and corn are common. Yields are lower than on Hall silt loam, Williams silt loam, and other comparable soils, principally because of the lower water-holding capacity. The maintenance of the organic matter and the prevention of soil blowing by careful management are the chief requirements for the continued productivity of this soil. Its present value as either cropland or grazing land is about 75 to 80 percent of that of Arnegard silt loam.

Cheyenne fine sandy loam.—This soil is situated on the terraces (second bottoms) along the larger streams. The surface is generally undulating. Most of the areas in the Sweetbriar Creek valley, however, are strongly undulating and have about as much variation in slope as the smoother soils of the uplands. The terraces for the most part are 12 to 30 feet above the level of the nearby streams. Surface drainage is good. Internal drainage varies from good to excessive, depending upon the depth of the soil above the underlying sand and gravel layers. Areas with less than 18 inches of brown soil, those underlain by gravel, and those with a sandy loam surface texture instead of a fine sandy loam are inclined to be droughty. The most extensive areas of Cheyenne fine sandy loam are in the lower part of Big Muddy Creek valley and in the valleys of Louse and Sweetbriar Creeks. The total area is 16.7 square miles.

The native vegetation varies somewhat with variations in surface texture, thickness of the brown soil layers over the underlying gravel and sand, and the nature of the underlying substrata. The areas that are less droughty have a cover of blue grama with a small quantity of niggerwool and needlegrass intermixed. The more droughty areas have a cover principally of blue grama and niggerwool.

The following is a generalized profile description of Cheyenne fine sandy loam:

- 0 to 10 inches, dark grayish-brown to very dark grayish-brown fine sandy loam that comes from place in irregular angular fragments that break under moderate pressure almost to single grains. The upper 4 or 5 inches are usually a little darker.
- 10 to 24 inches, dark grayish-brown fine sandy loam that gradually becomes lighter in color and coarser in texture. The depth of this layer may vary from 18 to 30 inches.
- 24 inches +, olive-yellow loamy fine sand that comes from place in soft easily crushed lumps. The depth to free calcium carbonate varies considerably, but it is generally correlated with the depth of the dark grayish-brown color. Where the soil is dark grayish brown to a depth of 25 or 30 inches, effervescence may not be observed within a depth of 45 or 50 inches; where the soil is olive yellow at a depth of 18 inches, effervescence may occur at 22 to 25 inches.

Included with Cheyenne fine sandy loam are a few areas that are underlain by gravel instead of sand at a depth of 10 to 25 inches. These areas are associated with Cheyenne loam, and the largest areas are in sec. 1, T. 140 N., R. 82 W. Parts of these areas have a sandy loam surface layer instead of a fine sandy loam, and some gravel is scattered throughout the soil. Another variation has a sandy loam surface underlain by sand to a depth of several feet. The following is a generalized profile description of this variation:

- 0 to 5 inches, dark grayish-brown to very dark grayish-brown sandy loam that comes from place as irregular lumps that are easily crushed.
- 5 to 18 inches, dark grayish-brown sandy loam. The lower part of this layer is lighter colored and more sandy.
- 18 inches to 6 or 10 feet, loose light-brown sand with little or no tendency to come from place in lumps below a depth of 28 inches. In several areas granitic gravel lies beneath the sand.

This variation occurs along the southern edge of the Heart River valley in T. 139 N., R. 81 W. and T. 139 N., R. 82 W.

The finer textured areas of Cheyenne fine sandy loam that have been tilled for many years with a moldboard plow have a well-developed plow sole similar to that described for areas of Flasher fine sandy loam that have been similarly plowed. The plow sole is less common in the sandier areas.

About 60 percent of Cheyenne fine sandy loam is tilled (pl. 3, B). The areas that are not tilled generally lie as irregular tracts along the creeks, where tillage is impracticable. Wheat is the principal crop, but barley, oats, corn, and hay, and flax to a lesser extent, are common crops. Corn, potatoes, and sorghums are well suited to this soil, especially to the finer textured areas. Crop yields vary considerably. Yields are better where the dark-brown material extends to a depth of 18 inches or more. In average good years wheat yields 10 to 12 bushels and corn about 25 bushels an acre. On the sandier and more gravelly tracts the yields average considerably less and the crops are less uniform. In general, small grains average about 20 to 30 percent and corn about 15 percent less on Cheyenne fine sandy loam than on Morton loam. The carrying capacity of virgin grass areas is about 65 percent of that of Morton loam.

Cheyenne fine sandy loam should not be exposed to the action of the wind. Likewise, precautions are needed to prevent the formation of a plow sole. Strip cropping and the use of duckfoot cultivators and other similar implements that minimize the stirring of the surface soil and at the same time incorporate crop stubbles and residues are proving to be effective measures for meeting these objectives.

Cheyenne gravelly loam, steep phase.—This phase consists of rolling or steeply sloping gravelly areas that lie on the escarpment edges of the gravelly alluvial benches or terraces. Surface and internal drainage are excessive, and none of the areas are suitable for tillage. The total area is 1.6 square miles. A large area is in the SW $\frac{1}{4}$ sec. 1, T. 140 N., R. 82 W.

Very little soil development has taken place. The 3- to 4-inch surface layer is dark grayish-brown gravelly loam, which effervesces almost to the surface when treated with acid. Below this relatively thin surface layer is gravelly material. On the few smoother parts the dark-brown gravelly loam extends to a depth of 6 to 8 inches and the 2- to 3-inch surface layer does not effervesce.

The native vegetation is mostly niggerwood, sandgrass, and little bluestem. Green sagebrush, skeletonweed, and purple coneflower are also common. Some blue grama occurs on the smoother parts.

This soil is used entirely for grazing, although the poor quality of the vegetation does not make it very desirable for such use. The carrying capacity is about 20 percent of that of Morton loam. Some of the areas are underlain by deposits of gravel that are suitable for road surfacing and concrete construction.

BROWNISH-GRAY SOILS OF THE TERRACES

The brownish-gray soils of the terraces are represented by one soil type—Cherry clay, which occurs principally on the low terraces along Big Muddy Creek. It has developed from fine-textured alluvial material. In comparison with the Hall or Cheyenne soils its gray color and shallow depth to carbonates indicate that it is a younger soil in terms of soil development.

Cherry clay.—This heavy dark brownish-gray clay soil occupies nearly level or very gently sloping areas on some of the benches or low terraces along the creeks. Both surface drainage and internal drainage are slow. Most of the areas are in Big Muddy Creek valley northwest of Almont. The total area is 2.1 square miles.

The native vegetation is mostly western wheatgrass and blue grama. Gray sagebrush is common in places. The grass cover is not so dense as on Grail silty clay loam or Arnegard silt loam, and in places the surface is noticeably exposed.

The following is a generalized profile description of Cherry clay:

- 0 to 3 inches, dark olive-gray clay that breaks easily to a mass of fine angular fragments. The pieces are fairly hard and resist crushing. Calcium carbonate is present throughout this surface layer as well as throughout the layer below.
- 3 to 15 inches, olive-gray clay that comes from place in large hard roughly prismatic lumps.
- 15 to 20 inches, slightly less hard olive-gray clay with white flecks of calcium carbonate.
- 20 to 30 inches, dark olive-drab clay with many flecks, particularly in the upper part.
- 30 inches +, olive-drab clay that is more friable and crushes fairly easily to small pieces.

There are a few areas in which the surface layer is darker and no carbonates are present above a depth of 12 inches or more. This variation of Cherry clay is somewhat similar to Hall clay, but it has a harder and denser consistence.

About 35 percent of Cherry clay is tilled, although there are many fields now abandoned that were once tilled. Wheat is the principal crop, but yields are not uniform, as the crop readily suffers from either drought or excess moisture. In occasional years when conditions are favorable for good crop growth, yields are about the same as those obtained on Hall silty clay loam.

Cherry clay is difficult to till because of the fine texture and hard consistence. If plowed when too dry, the soil turns up in large chunks that are difficult to work into a satisfactory seedbed unless it is plowed in the fall and allowed to slake or crumble during the winter. When wet the soil is a sticky, unworkable mass.

Cherry clay is most advantageously used as western wheatgrass meadow or as grazing land. The yield of western wheatgrass hay from virgin meadow areas averages about one-third of a ton to the acre; but the yield varies from year to year, depending upon the quantity and distribution of precipitation. As grazing land Cherry clay has a carrying capacity of about 70 percent of that of Morton loam.

DARK GRAYISH-BROWN TO LIGHT-BROWN SOILS OF THE ALLUVIAL FANS AND NATURAL LEVEES

The dark grayish-brown to light-brown soils of the alluvial fans and natural levees include three members of the Huff series—silt loam, very fine sandy loam, and loamy fine sand. The surface layers of the Huff soils are generally dark grayish-brown and differ in color from the light grayish-brown soils of the Huff series shown on the soil maps of McKenzie and Billings Counties. The subsoils and underlying materials for these soils in all three counties are similar in respect to their general light-brown to brownish-gray or olive-gray colors and also in respect to their origin and position as alluvial fan material on the stream terraces at the mouth of tributary valleys and as natural levees along the stream courses. These soils in Morton County may be considered to represent the more eastern or humid extreme of their range of characteristics.

Huff silt loam.—This shallow dark grayish-brown soil of the stream valleys is underlain by sandy alluvial fan and natural levee material. The surface is nearly level. Surface drainage is slow, but internal drainage is good or slightly excessive, especially on the more sandy areas that are natural levees. The principal areas are confined to the larger creeks and smaller rivers. Most of this soil occurs in the central and lower parts of Big Muddy Creek valley. It has a total area of 4.8 square miles.

The native vegetation is principally blue grama with niggerwool intermixed on the sandier parts and western wheatgrass on the heavier and finer textured areas. Gray sagebrush is also common in many areas.

A generalized profile of Huff silt loam is as follows:

- 0 to 5 inches, friable dark grayish-brown silt loam
- 5 to 10 inches, friable heavy silt loam with a fair prismatic structure. The color grades to grayish brown or brownish gray.
- 10 to 16 inches, grayish-brown to brownish-gray silt loam to clay loam without prismatic structure. The layer is generally calcareous at the top or within the upper 3 inches.
- 16 to 25 inches, olive-brown to olive-gray fine sandy loam. White flecks of calcium carbonate are abundant, particularly in the lower part of the layer. The bottom limit of this layer may vary from 22 to 40 inches.
- 25 inches +, olive-drab or dark olive-drab silty clay with numerous white flecks of calcium carbonate.

Several variations have been included with Huff silt loam. (1) There are areas in which the sandy layer is lacking. In such places the dark grayish-brown surface layer varies from silt loam to clay loam and grades directly into olive-drab silty clay. Such a soil should be classified as Cherry silt loam, but because of its limited acreage and its agronomic similarity to the Huff type it has been included with Huff silt loam. (2) There are a few areas in which the sandy material

lies within 10 inches of the surface. In such places the sandy material generally extends to a depth of at least $3\frac{1}{2}$ feet. (3) There are some areas in which the dark grayish-brown color extends to a depth of about 12 inches, the prismatic structure is well developed, and the soil is not calcareous until a depth of about 14 inches is reached. This variation corresponds closely with the Farland silt loam that is mapped on the terraces of McKenzie and Billings Counties, but because of its small acreage in Morton County it is included with Huff silt loam.

About 75 percent of Huff silt loam is tilled. Most of the uncropped areas are irregular tracts that border the channels of the creeks. Wheat is the most important crop and occupies about 50 percent of the total area. Flax, oats, barley, corn, and hay crops are the other important crops. The hay crops consist principally of the small grains (oats, barley, and wheat) cut green. In average good years wheat yields from 12 to 15 bushels, oats 25 to 30 bushels, and corn 20 to 30 bushels an acre. This is a fairly good soil for grazing, although the sandier sites are affected adversely by dry weather in a comparatively short time. The carrying capacity of the virgin areas is about 80 percent of that of Morton loam.

Huff silt loam is considered a desirable soil for general farming where the areas are not too severely cut up by meandering creeks. The comparatively shallow surface soil and light-colored subsurface layer indicate that the native fertility is considerably less than that of Hall silt loam. Although not markedly subject to soil blowing, Huff silt loam, because of its weaker structure and consequent somewhat greater tendency to break down to a fine-grained mass, is more subject to soil blowing than Hall silt loam.

Huff very fine sandy loam.—This soil is situated for the most part on the natural stream levees. It is relatively light colored, as only the surface few inches are dark grayish brown. The natural levees are nearly level. Some of the areas are badly dissected by the meandering channels of the streams. Drainage is good to excessive because of the sandy sublayers. The native vegetation for the most part is blue grama. The principal areas are in the Big Muddy Creek valley. The total area is 8.4 square miles.

The following is a generalized profile of Huff very fine sandy loam:

- 0 to 6 inches, dark grayish-brown very fine sandy loam or fine sandy loam that comes from place as easily crushed irregular fragments. This layer may vary from 5 to 8 inches in thickness.
- 6 to 14 inches, calcareous olive-brown very fine sandy loam or fine sandy loam with a structure similar to the layer above. With increasing depth the color gradually becomes lighter and the texture grades toward a loamy fine sand. In some places this layer extends to a depth of 16 inches.
- 14 to 40 inches, olive-gray loamy fine sand with small white flecks of calcium carbonate distributed throughout but concentrated somewhat at a depth of about 20 inches.
- 40 inches +, dark olive-drab silty clay with numerous white flecks of calcium carbonate. The material is fairly friable and generally has a fairly distinct angular nutlike structure. The depth to this layer varies from 3 to 6 feet.

Two variations have been included in the mapping of Huff very fine sandy loam. One is a soil with a dark grayish-brown to grayish-brown surface layer of very fine sandy loam to a depth of 8 to 12 inches. The soil material has no well-defined structure but comes from place in irregular fragments that are easily crushed to a fine-grained mass.

Below this layer the material gradually changes from olive brown to olive gray and the texture approaches a loamy very fine sand. The loamy fine sand generally extends to a depth of several feet, although olive-drab silty clay underlies some of the areas at a depth of 32 to 60 inches. When treated with acid effervescence takes place at a depth of 10 to 15 inches. Most of the areas of this variation are on the fairly high benches bordering the Missouri River, especially in the vicinity of Huff. The underlying material appears to have been wind-deposited, and the relief is undulating.

The second variation corresponds rather closely with the description given for Huff very fine sandy loam, except that the soil is not underlain by silty clay. Instead, olive-gray fine sand extends to a depth of several feet. This variation occurs principally on benches along the Heart River and lower Big Muddy Creek. The surface is nearly level, but in some places the areas are cut up by the meandering channels of creeks.

About 60 percent of Huff very fine sandy loam is tilled. Tillage of much of the remaining acreage is made impracticable because of the extent of dissection by stream channels, which in places become almost stream gorges. Wheat occupies about 30 percent of the total acreage. The other principal crops are corn, oats, barley, and other hay and forage crops. This soil is better suited to the deeper rooted crops, such as corn, sorgho, and potatoes, than to small grains.

In general, Huff very fine sandy loam is adapted to the same crops as Cheyenne fine sandy loam, but its productivity is a little lower except for the darkest colored and heaviest textured areas, which are better than the more sandy areas of Cheyenne fine sandy loam. Because of the hazard of soil blowing, care must be exercised with respect to cropping and tillage practices. The carrying capacity of virgin areas is about 65 percent of that of Morton loam.

Huff loamy fine sand.—This soil lies on the natural levees and benches along the larger creeks and is generally associated with Huff very fine sandy loam. The surface is gently undulating to undulating. Internal drainage is excessive. Most of the areas are cut up to some degree by tributary or meandering stream channels. The native vegetation is principally blue grama and sandgrass. The total area is 2 square miles.

Huff loamy fine sand has the following general profile features:

- 0 to 7 inches, dark grayish-brown loamy fine sand. The soil comes from place in weak structural lumps that break under little pressure to single grains.
- 7 to 14 inches, olive-brown loamy fine sand that is generally calcareous, although the depth of effervescence has been observed to vary throughout this layer.
- 14 inches +, olive-drab or olive-gray loose fine sand.

About 35 percent of Huff loamy fine sand is tilled, but some of the areas are cropped irregularly and remain idle a part of the time. Wheat, other small grains, and corn are the principal crops. Yields are low and are more variable from year to year than on the heavier soils. Low native fertility, droughtiness, susceptibility to blowing, the irregular distribution of the areas, and dissection by stream channels make Huff loamy fine sand better used as grazing land than as cropland. The carrying capacity is about 20 percent of that of Morton loam.

**VERY DARK TO DARK GRAYISH-BROWN SOILS OF THE TERRACES WITH CLAYPAN
(SOLODIZED-SOLONETZ) AREAS**

The very dark to dark grayish-brown soils with claypan (solodized-Solonetz) areas consist of Hall-Wade silty clay loams and Hall-Wade silt loams. These soil complexes consist of areas of Hall soils in which are located scab spots and areas of claypan. They are similar in many respects to the Morton-Rhoades and Grail-Moline complexes. These complexes differ from the Wade-Hall silty clay loams complex in having a smaller number of scab spots, a less extensive development of the claypan, a generally more dense and better grass cover, and consequently in being suitable in some degree for tilled crops.

Hall-Wade silty clay loams.—This complex represents areas of Hall silty clay loam in which scab spots and claypan areas (Wade soils) are irregularly or moderately distributed. The areas lie on the broad alluvial flats or low terraces of the larger creek valleys. The surface is nearly level, and both surface drainage and internal drainage are slow. Under average moisture conditions, however, drainage is sufficient for good crop growth on most of the areas. The principal areas are in the upper part of Big Muddy Creek valley and in the Little Heart River valley west of Saint Anthony. The total area is 24.9 square miles.

The native vegetation is a mixture of blue grama and western wheatgrass with a scattered growth of gray sagebrush. Saltgrass comes in noticeably on the more salty areas.

The following is a generalized description of an interspot area of Wade silty clay loam:

- 0 to 7 inches, dark grayish-brown to very dark grayish-brown friable silty clay loam. This surface layer varies in depth from 6 to 10 inches and grades abruptly to the layer below.
- 7 to 12 inches, a hard dense nearly black clay layer of columnar structure corresponding in general appearance to the claypan layer of Moline silty clay loam. When dry the material comes from place as hard sharply angular pieces $\frac{1}{4}$ to 1 inch in diameter. When wet the material is plastic and slick. Roots follow the vertical cracks.
- 12 to 20 inches, the color grades through a grayish brown to brownish gray and the material becomes more friable with depth. When treated with acid effervescence takes place within a few inches of the claypan.
- 20 inches +, olive-drab silty clay with numerous white flecks of calcium carbonate.

The scab spots are similar to those of the Grail-Moline areas (page 77). As in the other similar complexes, variations exist in the degree of development of the claypan, the range being from strongly developed claypans to soils showing no claypan.

About 85 percent of Hall-Wade silty clay loams is tilled. Wheat occupies about 55 percent of the total area. Other small grains and hay are important crops. In average good years wheat yields of 13 bushels and corn yields of about 22 bushels an acre are similar to those obtained from the Grail-Moline silty clay loams. Difficulties of tillage and the advantages of fall plowing are about the same as on that complex. The average carrying capacity is about 85 percent of that of Morton loam.

Hall-Wade silt loams.—This complex represents areas of Hall silt loam in which scab spots and claypan areas are irregularly or moderately distributed. The position and slope of the areas are similar to

those of Hall silt loam and Hall-Wade silty clay loams. Internal drainage is slow because of the underlying claypan, and surface drainage is slow because of the smooth surface. Drainage is sufficient, however, for the common crops during most seasons. Most of the areas are associated with Hall silt loam and Hall silty clay loam. The largest single tract is about 3 miles northwest of Schmidt. The total area is 12.4 square miles.

The native vegetation on the areas between the scab spots is principally blue grama and western wheatgrass. Many of the scab spots are grassed over, mostly with western wheatgrass and to some extent with buffalo grass.

The generalized profile of the interspot areas, except for texture, is similar to that of the corresponding parts of Hall-Wade silty clay loams. The surface layer to a depth of about 6 inches is very dark grayish-brown to dark grayish-brown silt loam. Immediately below this layer is the claypan layer. The scab spots likewise are similar in character to those described previously. The same variations in the character of the claypan and in the absence of the claypan exist in the areas between the scab spots as in the areas of the other complexes.

About 90 percent of Hall-Wade silt loams is tilled, and most of the acreage is used for growing the small grains, especially wheat. Yields are fairly good to good. Wheat averages about 14 bushels an acre in the average better years, and oats 22 to 28 bushels. The difficulties of tillage are not so great as on the heavier soils of the Hall-Wade silty clay loams complex. The western wheatgrass and blue grama furnish good wild hay and pasture. The carrying capacity of virgin areas is about 85 percent of that of Morton loam.

VERY DARK TO DARK GRAYISH-BROWN SOILS OF THE TERRACES WITH NUMEROUS CLAYPAN (SOLODIZED-SOLONETZ) AND SALTY (SOLONCHAK) AREAS

The very dark to dark grayish-brown soils of the terraces with numerous claypan (solodized-Solonetz) and salty (Solonchak) areas consist of only one complex—Wade-Hall silty clay loams. This complex consists essentially of areas of Wade silty clay loam with smaller sized areas of puff spots (Solonchak soils) in places, and of limited areas of Hall silty clay loam that are free of claypan development. Marked features of the landscape are the scab spots or depressions and the puff spots or low mounds of salty soils (Solonchak), both of which have been designated on the soil map as Wade-Hall silty clay loams. None of the areas are considered suitable for tillage.

Wade-Hall silty clay loams.—This complex occurs on the broader alluvial flats along the larger creeks. The surface is level or nearly so, and both surface drainage and internal drainage are generally slow. The most extensive areas are west and northwest of Saint Anthony, in the Little Heart River valley, and northwest of Glen Ullin in Big Muddy Creek valley. The total area is 25.7 square miles.

Two distinct kinds of soil complexes comprise Wade-Hall silty clay loams. The first includes the areas with the claypan (solodized-Solonetz) areas and the scab spots. The second consists of the areas of puff spots (Solonchak), with which are generally associated areas of

moderately developed claypan. Salt symbols have been added to the map to designate these puff-spot areas, which are about as extensive as the areas with the scab spots.

The areas with the scab spots and claypan development are similar to those of the Moline-Grail complex except for the differences in the source and nature of the parent materials, the topographic position, and the darker color of the surface soil. These areas also correspond to areas of Hall-Wade silty clay loams except for the greater number of bare or nearly bare scab spots, the greater prevalence of the claypan in the interspot portions, and the consequent lower productivity for grasses and general unsuitability for tilled crops. For generalized profile descriptions of the scab spots and claypan areas, reference may be made to the descriptions of Grail-Moline silty clay loams and Hall-Wade silty clay loams (pages 77 and 99).

The most noticeable landscape feature of the areas having puff spots is the low mounds, which rise from 6 to 12 inches above the associated parts and occupy from 25 to 60 percent of the areas in question. A generalized profile of the puff spot follows:

- 0 to 5 inches, friable dark grayish-brown to nearly black clay. A spade can be easily forced into this soil layer, and the material has a granular feel or structure, unless it has been puddled or kneaded to a plastic condition. The soil is almost always moist, and it remains so even during periods of prolonged drought.
- 5 to 12 inches, friable dark grayish-brown clay with abundant salt crystals. The crystals show no effervescence, but the soil in some places gives mild effervescence when treated with acid
- 12 to 18 inches, transitional zone of color change to olive drab.
- 18 inches +, olive-drab clay.

A generalized profile of the claypan areas between the puff spots is as follows:

- 0 to 3 inches, dark grayish-brown to very dark grayish-brown fairly friable silty clay loam.
- 3 to 7 inches, hard dense clay with a slightly darker color than above and a columnar structure. This layer is similar to corresponding layers previously described for Wade silty clay loam.
- 7 to 16 inches, the color grades to olive drab. When treated with an acid effervescence rarely occurs above a depth of 12 inches.
- 16 inches +, olive-drab clay.

The native vegetation on the puff spots is a moderate cover of saltgrass and seepweed, whereas on the areas between the puff spots there is a mixture of saltgrass and blue grama. The vegetation on the areas having a claypan associated with scab spots rather than puff spots is a mixture of blue grama, western wheatgrass, prairie junegrass, saltgrass, and some sagebrush, which is comparable to that on the Moline-Grail silty clay loams complex except that saltgrass is more common on this complex. The scab spots that are not bare generally have a sparse stand of saltgrass, small pricklypear, and western wheatgrass together with some annual weeds.

None of the area of Wade-Hall silty clay loams complex is suitable for tillage. The claypan and scab spots variation supports fair grazing and has a carrying capacity about 30 percent of that of Morton loam. The puff spot variation is relatively poor for grazing because of the preponderance of saltgrass and seepweed (*Suaeda*). The carrying capacity is about 10 percent of that of Morton loam.

SOILS OF THE BOTTOM LANDS

The soils of the bottom lands are on the first bottom lands of the river and stream valleys. On the basis of their several characteristics they have been placed in three subgroups: (1) Grayish-brown to brownish-gray soils underlain by silts, clays, and sands; (2) grayish-brown to brownish-gray soils underlain by sands; and (3) undifferentiated soils and land types.

GRAYISH-BROWN TO BROWNISH-GRAY SOILS UNDERLAIN BY SILTS, CLAYS, AND SANDS

The grayish-brown to brownish-gray soils underlain by silts, clays, and sands have been classified as members of the Havre soils. These soils are relatively gray, dark gray, or dark grayish brown, and because they are developing on relatively recent medium- to fine-textured alluvium they show little evidence of the regional type of soil development. The relief is nearly level except for low escarpments that indicate various levels of former stream overflow and deposition. Surface drainage is slow, but internal drainage is generally good except in the depressions where the water table may be high. These soils are generally desirable for general farming, except for the poorly drained areas, and the finer textured members are the most suitable soils in the county for irrigation. The principal crops are wheat, alfalfa, sweetclover, barley, oats, corn, and flax in the dry-farming areas. Truck crops, such as tomatoes, melons, cabbage, sweet corn, and potatoes, are grown on the few inextensive irrigated tracts.

Havre silty clay.—This soil is confined almost wholly to the first bottom lands along the Missouri River. The most extensive areas are southeast of Harmon and east of Fort Rice. A few very small areas are in the Heart River valley. The total area is 5.1 square miles.

Havre silty clay is developed from silty clay alluvium deposited principally by the Missouri River. The areas lie from 12 to 20 feet above the river. Surface relief is nearly level, and internal drainage for the most part is fairly good. Where the material is silty clay to a depth of several feet and free of sandy laminations, internal drainage is slower. Although this soil lies on the first bottoms along the larger streams, only under exceptional conditions is much of the acreage subject to flooding.

The native vegetation consisted largely of a forest of cottonwood in which were scattered small grassed openings. These stands of grass were probably western wheatgrass, as that is now the grass that establishes itself when forest and brush growth are cleared off. Very little of the cottonwood forest remains on this soil today. Areas that are not cleared are occupied by sweetbrier, buckbrush, dogwood, ash saplings, buffaloberry, and other similar brushy growths. Sweetclover has established itself where the brush growth is not too dense and consequently has increased the value of the areas for grazing.

The following is a generalized description of Havre silty clay:

0 to 8 inches, calcareous dark olive-gray friable silty clay. The soil comes from place in irregular fragments that are easily crushed to a mealy mass. The outside of the fragments is dark grayish brown, but the color of the crushed mass is dark olive drab.

8 inches to 3 feet, a series of laminated layers of deposited material, and consequently of variable character and thickness. Many of the layers are composed of dark olive-gray or slate-gray silty clay that breaks readily into angular well-defined hard fragments $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter that have no tendency to crumble. Other layers consist of dark grayish-brown or very dark grayish-brown friable silty clay that crushes easily to a crumbly mass. These two kinds of layers vary in thickness from 1 inch to 6 or 7 inches. Interspersed with these are thin lenses of grayish-yellow loose very fine sand.

3 feet +, grayish-yellow fine sand generally lies at a depth of 3 to 5 feet.

About 85 percent of Havre silty clay is cleared, 10 percent of which is used as western wheatgrass meadow. Wheat occupies about 50 percent of the total acreage. Most of the remaining cleared part is used for alfalfa, sweetclover, barley, oats, corn, and flax. Alfalfa is more often grown on this soil than on any other, although the total acreage is small. Most of the irrigated land of Morton County is on this soil. Water is drawn from the adjacent rivers—generally the Missouri River—by tractor-driven centrifugal pumps and is distributed through shallow surface ditches. All crops respond well to irrigation.

Yields of all crops are comparatively good and approach those obtained on Williams silt loam. Yields of alfalfa (pl. 11, C) in average good years are from 1 to 2 tons an acre. According to information obtained from the Lower Yellowstone Project, Montana-North Dakota, in McKenzie County average yields on Havre silty clay under irrigation are about as follows: Alfalfa, 3 to 4 tons or more to the acre; wheat, 30 bushels; corn, 40 bushels; and barley, 40 bushels. Experiences with the few small tracts now irrigated in Morton County indicate that alfalfa and the numerous truck crops grown can be produced satisfactorily under irrigation.

Although Havre silty clay has a heavy texture, it is comparatively easily handled because of the friability that results from the high content of calcium carbonate. Very little of this soil is burdened with alkali or an excess of other salts even though it has a high lime content. It is adapted to a wide range of crops and consequently is one of the most suitable soils for general farming. Under dry-farming operations the use of commercial fertilizers probably is not justified. Where irrigation is practiced, however, the use of phosphate fertilizer is desirable, particularly for alfalfa.

The carrying capacity of cleared areas as grazing land is at least equal to that of Morton loam, and proper irrigation greatly increases it.

Havre silty clay, poorly drained phase.—This phase includes all of the poorly drained soils of the river bottoms that have a clayey texture (silty clay loam, silty clay, clay) to a depth of 14 inches or more. Most of it is in the Missouri River valley, where much of it lies in gentle depressions bordering the higher lands at the edge of the first bottoms. The surface is nearly level or slightly concave, and both external and internal drainage are very slow. The total area is 2.8 square miles.

The uncleared areas have a mixed brushy growth of buckbrush, dogwood, wild rose, ash, boxelder and cottonwood saplings, and diamond and other willows. The willows are confined to the most poorly drained areas. Sweetclover is distributed through this brushy growth on many of the areas and increases the grazing value accordingly.

A general description of the profile is as follows:

0 to 12 inches, medium slate-gray or dark slate-gray silty clay, generally slightly mottled with yellow. The amount of mottling increases with depth. In places small orange-colored specks are distributed through the soil, especially in the upper several inches. The soil comes from place in large firm chunks that break easily when moist to a friable crumbly mass. When treated with acid effervescence occurs throughout.

12 inches +, thin beds or laminations of slate-gray, light-gray, and yellow silt and clay with some white flecks of calcium carbonate. The lighter colored layers are more calcareous than the darker colored ones.

About 70 percent of Havre silty clay, poorly drained phase, is cleared, but only a small part is tilled, as the greater part is used as hay meadowland. The higher lying areas have fair to good stands of western wheatgrass, but most of the land has a growth of sedges, smartweed, and blue wild lettuce. Sweetclover, where it has become established, affords good hay and grazing. The small areas that are farmed are used principally for wheat, corn, and hay crops. Although yields are good in favorable seasons, most of the acreage of this soil is better suited for meadowland or grazing than for tilled crops. Yields of hay range from 1 to 2 tons.

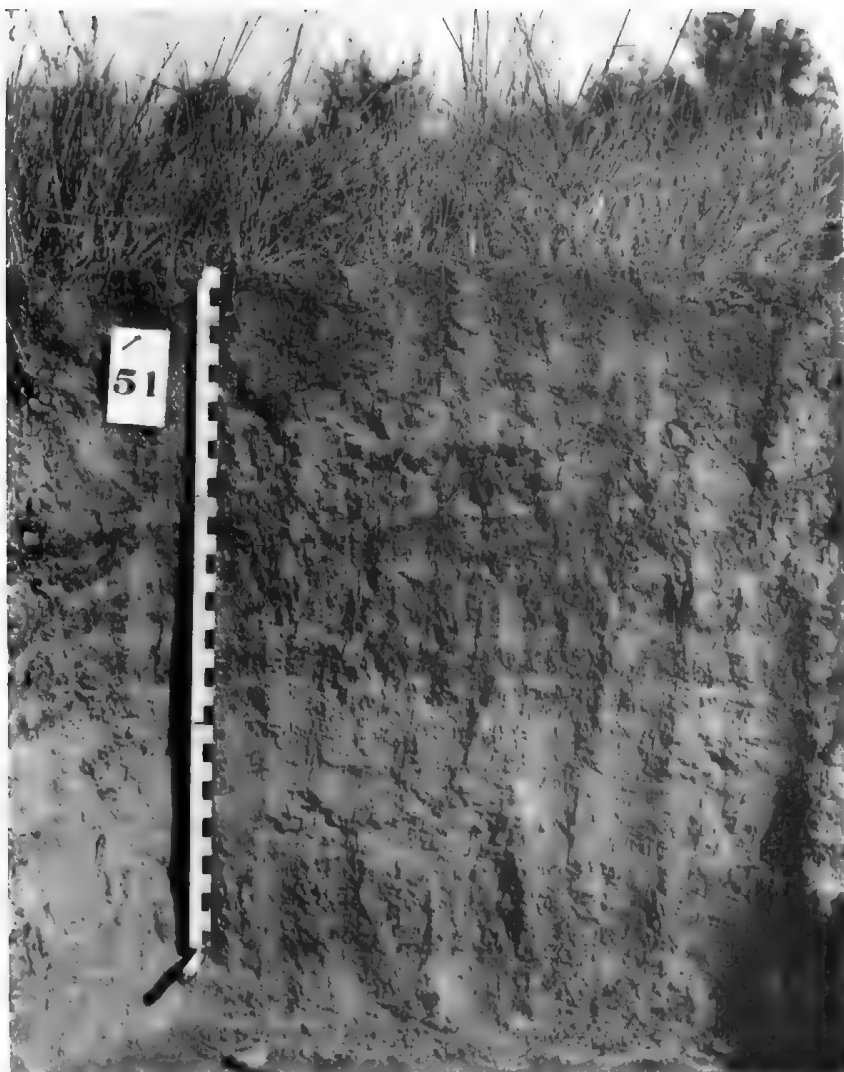
Cleared areas on which a good type of grass cover has been established have a carrying capacity somewhat greater than that of Morton loam, but because the vegetation on most of the cleared areas includes a great abundance of sedges, the average carrying capacity is about 85 percent of that of Morton loam. The areas with the cover of brush have a considerably lower carrying capacity, although where sweetclover is intermixed cattle are able to obtain considerable feed during the summer months.

Havre silt loam.—This soil differs from Havre silty clay, with which it is associated, principally in the less heavy texture and consistence of the upper layers. The total area is 2.9 square miles. The surface is nearly level to gently undulating, and because of the greater quantity of sand in the sublayers (pl. 12), internal drainage is more rapid than in the silty clay, but not enough so to be detrimental to crop growth except during the very dry seasons. On the other hand, in the seasons of excessive moisture the better internal drainage is an asset over the silty clay. Similarly, this soil is generally more desirable for irrigation because of the better but not excessive percolation of water (pl. 13, 4).

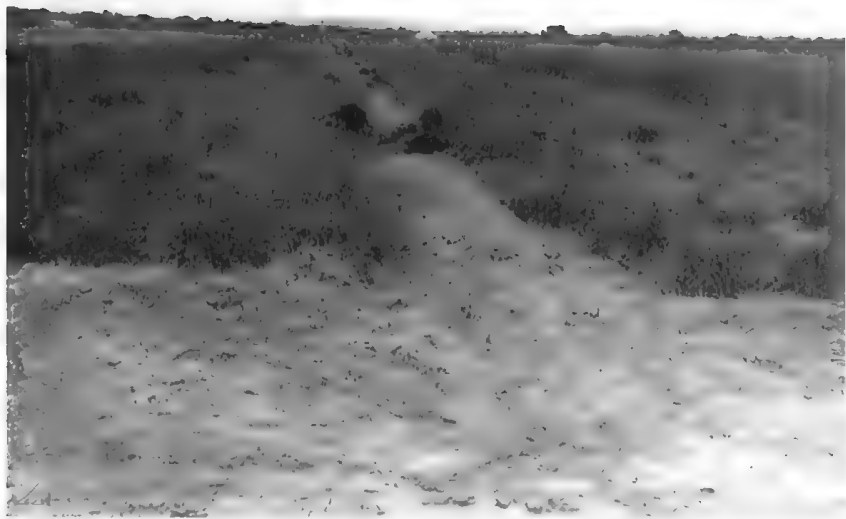
Two general variations exist. Some areas have a brownish-yellow friable silt loam layer that extends to a depth of about 12 inches, below which silt, silty clay, and sandy laminations similar to those in Havre silty clay occur. Other areas have a silty clay surface, below which are more pronounced sandy layers in the upper subsoil, which give the upper 18 inches a texture that is coarser than that in the other variation or in the silty clay type. Carbonates occur throughout the profile of both variations.

About the same proportion of this soil is cleared, the same types of farming are followed, and the same crops are grown as on Havre silty clay. Likewise yields are about the same on the two soil types.

Havre fine sandy loam.—This soil type represents, for the most part, areas of Havre silty clay or silt loam that have had sandy material deposited on them by tributary creeks overflowing on areas of



A profile of Havre silt loam showing alternate silt and sand layers and platy breakage.



A, Irrigated grasses grown on Havre silt loam on the grounds of the Soil Conservation Service nursery near Mandan. **B**, Alfalfa and other farm crops, brush, and cottonwood trees on the Missouri River bottom lands south of Mandan. Bismarck and State Capitol Building are shown in the background. Most of the area of Banks loamy fine sand is in timber or brush. Havre silt loam is well suited to alfalfa.

these finer textured soils. The aggregate area is 1.7 square miles. All of it is in the Missouri River valley, and the largest area is in the northwest part of T. 140 N., R. 81 W. The surface is nearly level, and the drainage is good.

The surface layer of grayish-brown fine sandy loam varies in thickness from 4 or 5 inches to about 14 inches. Below this are the friable dark olive-gray silty clay or silt loam layers similar to those described in the surface layers of Havre silty clay or Havre silt loam. The entire profile effervesces when treated with acid.

Approximately 90 percent of Havre fine sandy loam is cropped. It is used mostly for wheat and other small grains, but it is also well suited to the production of row crops, such as corn and potatoes. Yields are good and average very nearly the same as on Havre silty clay and Havre silt loam. The soil is easily worked, and for this reason during moist periods it is preferred to the heavier types. Certain portions, at least, appear to be suitable for irrigation. The carrying capacity of the areas in the mixed native grasses and brush is about 70 percent of that of Morton loam or Havre silty clay.

GRAYISH-BROWN TO BROWNISH-GRAY SOILS UNDERLAIN BY SANDS

The grayish-brown to brownish-gray soils underlain by sands are members of the Banks series. These soils are relatively light colored (light brown and gray) and young, as they are developing on recently deposited sandy alluvium that is still subject to overflow. The textures of the surface layers vary according to the soil type from silty clay to loamy fine sand. The relief ranges from nearly level to hummocky, and the areas are commonly cut by old stream channels. Although internally the soils are well to excessively drained and surface water is rapidly absorbed, the drainage is variable, depending upon depth to the water table. Scattered to rather dense stands of cottonwood occur here and there.

Banks very fine sandy loam and silty clay are fairly productive and desirable for farming purposes, whereas Banks loamy fine sand is too droughty and hummocky, and Banks silty clay, poorly drained phase, is frequently too wet.

Banks very fine sandy loam.—This grayish-brown or light-brown very fine sandy loam soil of the river bottom lands is underlain by sand to a depth of several feet. It is one of the most extensive soils on the flood plains of the Heart and Cannonball Rivers, where it generally occupies the main part of the valley, except for narrow strips of Banks loamy fine sand along the river channels. Fairly extensive areas are situated also in the Missouri River bottom lands, where they lie as a belt between the more extensive Havre soils of the main part of the valley on the one side and a narrow strip of Banks loamy fine sand that is adjacent to the river on the other side. The total area is 7.3 square miles.

The surface is very gently undulating to gently billowy. Generally, the more uneven or the more billowy the areas are, the more sandy is the soil. Internal drainage is excessive except in the slight depressions between the undulations or billows. The lower lying areas are subject to periodic floods.

It appears that most of this soil, especially in the Missouri River valley, was occupied by a good stand or forest of cottonwood. From

remnants of the virgin stand it appears that the average size of the trees was 18 to 28 inches in diameter. At the present time most of the uncleared areas are occupied by cottonwood, buckbrush, buffaloberry, wild rose, and other shrubby growth. On most areas in the Missouri River valley sweetclover is intermixed with the trees and brush. On the cleared but untilled areas the cover consists principally of a sparse growth of blue grama and niggerwool intermixed with a considerable stand of sandgrass. In many places sweetclover makes up a good part of the cover and enhances the grazing value of the areas.

The following is a generalized profile description of Banks very fine sandy loam:

0 to 7 inches, calcareous grayish-brown very fine sandy loam. The material comes from place in irregular pieces or fragments that are easily crushed to fine grains. This surface layer varies in depth from 5 to 10 inches. In some places effervescence occurs within a few inches of the surface instead of at the surface.

7 to 15 inches, the color grades to brownish yellow or grayish yellow and the soil becomes increasingly sandy with depth.

15 inches +, grayish-yellow loose fine sand.

A few of the areas shown on the map have a surface layer of about 12 inches that is more nearly a silt loam than very fine sandy loam. Varves, or thin lenses, of silty clay generally account for the slightly heavier texture. Below the silt loam surface layer is grayish-yellow loose fine sand.

Probably 85 percent of Banks very fine sandy loam in the Heart and Cannonball River valleys is tilled. A much smaller part of that in the Missouri River valley is cropped. The tilled areas are used largely for growing feed crops. The principal crops are rye, oats, and barley, raised for grain and hay, and corn. Some wheat and flax are also grown, but they are not as common as on the dark grayish-brown loamy soils of the uplands. Some alfalfa and sweetclover are also grown for hay, but the total acreage is small.

Because of the sandy surface soil and the droughty subsoil, the small grains produce only fair yields. Rye is the most satisfactory small-grain crop, as it matures at an earlier date than the others, and consequently it is less likely to suffer from hot, dry midsummer weather. Rye is less apt to winterkill on sandy soils, such as this, than on the finer textured soils. In average good years rye yields 12 to 16 bushels an acre. Deeper rooted crops, such as corn, potatoes, alfalfa, and sweetclover, are well suited to this soil. Corn yields 20 to 25 bushels an acre, potatoes 60 to 100 bushels, and alfalfa and sweetclover from 1½ to 2 tons. Wheat yields are about the same as those obtained on the other sandy soils.

The porous nature of Banks very fine sandy loam, particularly of the sublayers, and its generally uneven or slightly billowy surface, make it of doubtful value as irrigable land. It is also subject to wind erosion; consequently it should be cropped and tilled in such a way as to avoid wind action as much as possible. Fall-sown rye is of considerable advantage in this respect, provided there is sufficient moisture to establish a stand at that time. Alfalfa is likewise a desirable crop to protect this soil, but satisfactory results on the sandiest areas cannot ordinarily be expected.

The carrying capacity of cleared native grassed areas is about 40 percent of that of Morton loam or Havre silty clay. Where a good stand of sweetclover is established the carrying capacity is greater.

Banks loamy fine sand.—This soil is the most extensive and widely distributed of the first bottom land soils of the river valleys. Its aggregate area is 13.7 square miles. It occurs throughout the valleys of the Missouri, Heart, and Cannonball Rivers. It is by far the predominant first-bottom soil along the Heart and Cannonball Rivers, and it occupies extensive areas along the Missouri River. Most of the areas in the Missouri River valley occur as strips that border the river channel on the bank opposite to the cutting side of the river. They represent, to a great extent, areas of river alluvium of comparatively recent deposition. Whereas this soil generally occurs as strips bordering the river channel in the Missouri River valley, it commonly occupies the entire valley of the smaller river valleys.

The surface of Banks loamy fine sand is undulating to gently billowy. The drainage, because of the extremely sandy sublayers, is excessive. The areas that lie farthest from the river channels and have a smooth relief generally have sufficient water-holding capacity and sufficient fertility to produce occasionally fair yields of some of the crops.

The native vegetation was for the most part cottonwood. This forest growth, especially next to the river channels, consisted of trees ranging in diameter from 18 to 28 inches. The trees on the drier sites were not so large. At present the uncleared areas are occupied by brush or cottonwood or a mixture of the two (pl. 13, *B*). The cottonwood growth varies from poor to medium stands of saplings. The brush growth consists principally of buffaloberry, wild rose, and short buckbrush, and in many places sweetclover is intermixed with this growth. The sweetclover is the most desirable edible plant that grows to any great extent on this soil. The cleared part that is not tilled is occupied by sandgrass and in some places by blue grama.

The following is a generalized profile description of Banks loamy fine sand:

0 to 5 inches, light-brown loamy fine sand or fine sand that comes from place in soft easily crushed pieces. This layer is calcareous, as effervescence generally takes place at or within a very few inches of the surface when treated with acid.

5 to 12 inches, the soil gradually becomes lighter in color and more sandy with depth.

12 inches +, loose olive-gray sand.

At the present time about 40 percent of Banks loamy fine sand is either completely or partly cleared. Only a small part of the cleared acreage is tilled. Corn and rye are probably the most common crops, but yields are low and uncertain. Because of unprofitable yields and great susceptibility to blowing, this soil should be left in its virgin condition and used either for grazing or for the production of cottonwood and other useful forest growth. Because of its droughty nature and the poor type of grazing vegetation on it, the carrying capacity of this soil is very low. It is about 15 percent of that of Morton loam.

Banks silty clay.—This is the grayish-brown silty clay soil of the first bottom lands that is underlain by sands. The most extensive area is on the Missouri River bottom lands. The total area is 3.3 square miles. For the most part the surface is nearly level, although

some of the areas are slightly billowy. Internal drainage is somewhat excessive because of the shallow depth at which sand is present. The native vegetation is similar to that on Havre silty clay.

Banks silty clay has the following generalized profile:

0 to 10 inches, calcareous dark olive-gray or dark olive-brown friable silty clay.

This layer is similar to the surface layer of Havre silty clay.

10 inches +, calcareous grayish-yellow fine sand, extending to a depth of several feet.

The areas along the Heart River are a little more brownish and the soil generally lacks the fragmentary structure that is common to Havre silty clay and to the Banks silty clay of the Missouri River valley. Carbonates are abundant throughout the profile.

About 45 percent of the area of Banks silty clay in the Missouri River valley and about 90 percent of it in the Heart River valley are tilled. Such areas are used for general farming. Wheat is the most important crop, but it is less predominant, particularly throughout the Heart River valley, than on such soils as Morton loam. Barley and oats, for grain and hay, and corn are also grown. Yields are not so large or so regular as those obtained on the Havre soils. The sand lies so near the surface that the reserve moisture supply that this soil is capable of holding is small.

Because of the sandy subsoil, only the smoothest areas that have relatively thick silty clay surface soils are suitable for irrigation. Practically none of this soil is being irrigated at the present time. Those areas that have been found to be suitable for irrigation are adapted to the same crops as the Havre soils.

The carrying capacity of virgin cleared land is nearly equal to that of Morton loam. Those areas in which the sand sublayers are nearest the surface have a lower carrying capacity.

Banks silty clay, poorly drained phase.—This phase consists of the poorly drained areas that are associated with the Banks soils, principally in the Missouri River bottom lands. Most of these areas are near the Missouri River, whereas the areas of Havre silty clay, poorly drained phase, are on the low-lying areas farther from the river. Some of the areas occupy old stream-channel depressions, and others occur in the low-lying billowy areas in which recent deposition by the river has taken place. Much of this phase is subject to floods. The total area is 0.9 square mile.

Most of the areas are covered by a brushy growth consisting of buckbrush, dogwood, boxelder, ash, and cottonwood saplings. The lowest areas are covered by a growth of willows.

Banks silty clay, poorly drained phase, has the following generalized profile:

0 to 10 inches, dark slate-gray silty clay that breaks into small angular fragments. The material is less apt to be mottled than the corresponding layer of Havre silty clay, poorly drained phase. In the lower lying areas, $\frac{1}{2}$ inch of cracked and checked gray mud covers the surface. The depth of this surface layer varies from 8 to 12 inches.

10 inches +, gray loose very fine sand or fine sand.

Low swells or ridges on which the surface soil is not as deep as given above have been commonly included in the areas designated on the soil map. In many places on the knolls the texture of the surface soil is very fine sandy loam. A few areas have a grayish-brown fine

sandy loam surface layer underlain at a depth of about 12 inches by slate-gray silty clay mottled with yellow.

Practically none of this phase is tilled. The cleared areas have a grazing capacity slightly lower than that of the cleared areas for Havre silty clay, poorly drained phase, and the uncleared areas are about equal to or of slightly less value than the uncleared areas of the same soil.

UNDIFFERENTIATED SOILS AND LAND TYPES

The undifferentiated soils and land types are all developed on stream alluvium and for the most part are subject to inundation during flood stages of the streams. They are variable in character and do not show evidence of the development of soil layers. Only a few small areas are suitable for tillage, and the grazing value differs widely because of the variations in soil materials, conditions of drainage, quantity of soluble salts, and consequent character of the vegetation. This group consists of Alluvial sandy soils, undifferentiated; Alluvial loam soils, undifferentiated; Alluvial clay soils, undifferentiated; and Riverwash. The undifferentiated soils for the most part occur along the smaller streams, and Riverwash is mapped chiefly along the Missouri River.

Alluvial sandy soils, undifferentiated.—These soils include strips of irregular sandy alluvium along the creeks and smaller streams, principally within the watershed of the Cannonball River. The aggregate area is 4.6 square miles. The surface is bumpy or hummocky, as the areas are composed of bench remnants, natural levees along the stream channels, abandoned gorgelike stream channels, and other depressions common to first bottom lands. The drainage varies from excessive on the sandy natural levees to poor in the abandoned stream channels and depressions, and these soils are subject to occasional flooding.

The vegetation on the better drained areas is predominantly blue grama. A scattered growth of buckbrush or gray sagebrush is common in some places. Sandgrass, peppergrass, Russian-thistle, and other weeds are also common. The lower lying areas have a heavier growth of grasses and brush. Saltgrass grows on the areas in which salt accumulations have developed.

The profile character is variable. In general the 4- to 5-inch surface layer is grayish-brown loamy fine sand or fine sandy loam that is generally loose and very weakly bound by grass roots. Below this is light-brown loose fine sand that becomes grayer with depth. The depth at which effervescence takes place varies; frequently it is at or near the surface.

Practically none of this soil complex is cultivated, as it is generally too sandy, the surface is too irregular, and the areas are too badly dissected by streams to permit successful tillage. The areas furnish only fair grazing because of the droughtiness of the soil and the comparatively poor quality of the grasses. The carrying capacity is about 25 percent of that of Morton loam.

Alluvial loam soils, undifferentiated.—For the most part these soils represent strips of irregular alluvium lying along the creeks and smaller streams and averaging a loam to a silt loam in texture. Parts of the total area are composed of lobes or tongues of the associated soils of the

Huff and Hall series that are too small or too isolated by stream meanders to be mapped in their respective types. Old stream channels and inextensive low-lying alluvial benches and fans that have been reassorted by stream action are also included, as these latter areas are invariably subject to inundation during flood periods, whereas the remnant areas of the Wade, Huff, and Hall soils are seldom flooded. This soil complex is distributed widely over the county. The aggregate area is 36.4 square miles.

The surface is irregular or extremely hummocky. Drainage varies widely; that of the higher parts is good, whereas that of the lower parts is poor. The lowest parts have an accumulation of salts, due to seepage water from the adjoining higher lying areas.

Although scattered small areas of the Hall and Huff soils are tilled and farmed according to the methods practiced on those respective soils, the areas of Alluvial loam soils, undifferentiated, in general are not suitable for tillage. They are best utilized as grazing land, and as such they vary widely in value. Those parts composed of remnants of Hall soils afford good grazing, as do also the lower parts that are well grassed and are not burdened by an accumulation of salts. Those parts, however, that are poorly drained and have an accumulation of salts afford little grazing. The average carrying capacity of this soil complex is about 75 percent of that of Morton loam. Extensive areas that are noticeably salty are indicated on the map by appropriate symbols and have a carrying capacity considerably lower than that of the comparatively salt-free areas.

Alluvial clay soils, undifferentiated.—These soils differ primarily from the loam separation in having a clay rather than a loamy texture in the surface material. A greater part of the total area is composed of low-lying alluvium, and consequently a smaller part is composed of remnants of soils of the Hall and Huff series. The total area of this soil complex is 10.1 square miles. It is widely distributed over the county. It occurs along the smaller creeks or streams, whereas the loam separation is more common along the larger creeks. Drainage is poor except for the occasional included areas of Hall and Huff soils. The relief is irregular or hummocky, and very few if any of the areas are suitable for tillage.

In general, this material is dark-gray clay that generally grades to mottled dark-gray and yellow clay at a depth of from 5 to 14 inches. Salt symbols are used on the soil map to indicate areas affected by an accumulation of soluble salts. Such areas constitute a large part of the total acreage.

The native vegetation on the well-drained parts is generally blue grama. The lowest or most poorly drained parts are boggy and are occupied for the most part by lowland sedges. Those areas inclined to be salty are occupied chiefly by saltgrass and seepweed. Arrowgrass, a poisonous plant, also is common on such areas, particularly where the soil is perpetually moist. The average carrying capacity of this land is low, especially on the salty areas. Only the very best areas have a carrying capacity approaching that of the loam separation.

Riverwash.—This mapping separation represents very recent deposits of sandy alluvium along the rivers. The low-lying areas consist of grayish sand or fine sand that exhibits no signs of soil development.

Most of the areas are only a few feet above the surface of the rivers, and they generally occur as strips bordering the river channels on the side opposite from the cutting side of the stream.

The total area of Riverwash is 1.3 square miles. Over 95 percent of it is along the Missouri River. The surface is gently billowy, and practically all of the areas are subject to annual inundation. About 50 percent of the acreage is bare. The rest is covered by a growth of either willow or cottonwood saplings. Riverwash has practically no agricultural or grazing value.

PRODUCTIVITY RATINGS AND PHYSICAL LAND CLASSIFICATION

In table 5 estimates are given by means of indexes of the approximate yields obtained for the crops commonly grown on each soil type under the common farming practices. Estimates are given for average yields over a period of years, and also for the average of the better years. It cannot be overemphasized that the indexes are largely estimates.

The indexes compare the productivity of each of the soils for each crop with a standard of 100. This standard index represents the productivity, without the use of amendments or fertilizers, of the more productive soils of the region in which the crop is commonly grown. An index of 50 indicates that the soil is about half as productive for the specified crop as the soil with the standard index. Soils given amendments, such as lime or commercial fertilizers, or unusually productive soils of small extent may have productivity indexes of more than 100 for some crops.

The principal factors determining the productivity of land are climate, soil, and management. Under the term "soil," as used here, conditions of slope, stoniness, and drainage are included. Climate as a factor in crop production cannot be isolated from the soil factor, inasmuch as climate determines in part the type of soil. In Morton County, however, variations of the seasonal climate from year to year are very pronounced in their effect upon crop production and overshadow the soil condition. As a result, the productivity of the land is rather definitely associated in the experience of the farmer with climate, particularly the amount and time of precipitation and the presence or absence of hot winds. Other elements that contribute to determine actual yields obtained by the farmer in Morton County are the infestation of insects, such as grasshoppers, and the prevalence of fungi, such as black stem rust. Two soil conditions of particular importance to productivity in this county are the content of soluble salts and the degree of saturation by sodium. Since these conditions are commonly associated and result in a series of bare circular spots locally known as scab or gumbo spots, distinctly scabby areas are mapped separately (see descriptions for claypan and salty soils).

These factors of soil, climate, and management do not operate independently of one another, and the productivity of all soils cannot be measured directly by any one of them. Crop yields over a long period of time furnish the best available summation of the combined effect of the factors, and they are used as a basis for the indexes wherever they are available. A lack of substantial data concerning yields on individual soil types in Morton County has resulted in the indexes

TABLE 5.—*Productivity ratings of soils of Marlon County, N. D.*

DRY FARMING

Soil	Crop productivity index 1 for—											
	Corn (grain) 100=50 bu		Corn (fodder) 100=12 tons		Wheat 100=25 bu.		Barley 100=40 bu		Oats 100=30 bu		Flax 100=15 bu.	
	A	B	A	B	A	B	A	B	A	B	A	B
Amesgard silt loam.....	40	60	30	40	50	80	50	75	50	80	60	90
Trimmer loam.....	40	60	30	40	50	75	45	70	45	70	60	90
Hall silt loam.....	35	55	25	35	50	75	40	65	40	65	55	85
Hall silty clay loam.....	30	50	20	30	45	70	45	70	45	70	50	80
Hall loam.....	35	55	25	35	45	70	40	65	40	65	50	80
Grail silt loam.....	40	60	25	35	65	85	40	60	40	60	50	80
Grail silty clay loam.....	35	55	20	30	45	65	40	60	40	60	45	75
Havre silt loam.....	40	60	25	35	40	65	40	65	40	65	45	75
Williams silt loam.....	35	55	20	30	40	65	40	65	40	65	35	60
Havre silty clay.....	35	55	20	30	40	65	40	65	40	65	35	60
Williams silty clay.....	30	45	15	25	40	60	35	60	35	60	40	65
Morton loam.....	35	55	20	30	35	60	35	60	35	60	35	65
Cheyenne loam.....	35	55	20	30	35	60	35	60	35	60	35	65
Morton clay loam.....	30	45	15	25	35	60	35	60	35	60	30	45
Turner fine sandy loam.....	30	55	20	30	40	55	40	55	40	55	40	65
Gearing loam.....	35	55	20	30	30	55	30	55	30	55	40	65
Havre fine sandy loam.....	30	50	20	30	30	55	35	55	35	55	35	60
Huff silt loam.....	35	55	20	30	30	55	30	55	30	55	35	60
Hall-Wade silt loams.....	35	55	20	30	30	55	30	55	30	55	30	55
Banks silty clay.....	25	45	15	25	30	55	25	50	25	50	25	40
Patent clay loam.....	25	40	15	25	30	55	25	50	25	50	25	40
Grail-Moline silt loams.....	20	40	15	25	30	55	25	50	25	50	25	40
Grail-Moline silty clay loams.....	20	40	15	25	30	55	25	50	25	50	25	40
Grail-Moline silty clay loams.....	20	40	15	25	30	55	25	50	25	50	25	40
Grail silty clay loam, slope phase.....	30	45	15	25	35	50	30	45	30	45	35	50
Grail silty clay loam, slope phase.....	30	45	15	25	35	50	30	45	30	45	35	50
Phaser silty clay loam.....	25	45	15	25	35	50	30	45	30	45	35	50
Hall-Wade silty clay loams.....	25	45	15	25	35	50	30	45	30	45	35	50
Fisher fine sandy loam.....	30	50	15	25	30	45	25	40	25	40	30	45
Cheyenne fine sandy loam.....	30	50	15	25	35	45	25	40	25	40	30	45
Banks fine sandy loam.....	25	45	15	25	35	45	25	40	25	40	30	45
Morton-Rhodes loams.....	25	40	15	25	35	45	25	40	25	40	30	45
Morton-Rhodes clay loams.....	25	40	15	25	35	45	25	40	25	40	30	45
Barville loam, smooth phase.....	25	40	15	25	35	45	25	40	25	40	30	45
Patent-Moline silt loam.....	25	40	10	25	25	45	25	40	25	40	30	45

Grail-Moline silty clay loams, slope phase	20	35	10	20	30	45	30	45	30	45	15	25	30	50	10	20	25	40	25	4
Bainville clay loam, smooth phase	20	35	10	20	25	45	25	40	25	40	30	50	30	55	15	25	15	25	20	3
Cherry clay	20	35	10	20	25	45	20	35	20	35	25	45	10	20	30	55	10	15	25	30
Patent-Moline clay loams	20	35	10	20	25	45	20	35	20	35	25	40	---	---	---	---	---	15	25	30
Huff very fine sandy loam	30	50	15	25	25	40	20	35	20	35	20	35	---	---	25	45	15	30	45	20
Morton loam, rolling phase	25	35	15	20	25	40	25	35	25	40	25	40	---	---	30	55	10	20	25	40
Morton clay loam, rolling phase	20	30	10	20	25	40	25	35	25	40	25	40	---	---	30	55	10	20	25	40
Fisher loamy fine sand, smooth phase	20	35	10	20	20	30	20	30	20	30	20	30	---	---	20	35	15	30	20	30
Patent-Moline fine sandy loams	20	35	10	20	20	30	20	30	20	30	20	30	---	---	20	35	15	30	20	30
Patent loamy fine sand	15	30	10	20	20	30	20	30	20	30	15	30	---	---	20	30	15	25	20	30
Bainville-Rhodes loams	15	30	10	20	15	30	15	30	15	30	15	25	---	---	20	35	10	15	20	35
Patent clay loam, slope phase	15	25	10	20	20	30	20	35	20	30	20	30	10	30	25	40	15	20	15	25
Bainville loam	15	25	10	20	20	30	20	30	20	30	20	30	---	---	20	35	15	25	15	20
Bainville clay loam	15	25	10	20	20	30	20	30	20	30	20	30	---	---	20	35	10	20	15	20
McKenzie clay (better areas)	15	25	10	20	20	30	20	30	20	30	20	30	---	---	10	20	---	---	15	20
Bainville-Rhodes clay loams	10	25	10	20	15	25	15	30	15	30	15	25	---	---	20	35	10	15	30	15
Searing loam, rolling phase	15	25	10	20	15	25	15	25	15	25	15	25	---	---	15	25	10	20	15	25
Huff loamy fine sand	15	25	10	20	10	20	10	20	10	20	10	20	---	---	---	---	10	15	25	---
Fisher fine sandy loam, rolling phase	15	25	10	20	10	15	10	15	10	15	10	15	---	---	20	30	10	20	15	25
Morton-Rhodes clay loams, rolling phases	10	15	5	10	10	15	10	15	10	15	10	15	---	---	10	20	---	10	20	---
Patent-Moline clay loams	5	10	5	10	10	15	10	15	10	15	10	15	---	---	10	20	---	10	20	---
Bainville-Rhodes loams, rolling phases	5	10	5	10	5	10	5	10	5	10	5	10	---	---	5	10	---	10	15	5
Bainville-Rhodes clay loams, rolling phases	5	10	5	10	5	10	5	10	5	10	5	10	---	---	5	10	---	10	15	5
Fisher loamy fine sand	---	---	---	---	10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Moline-Grail silty clay loams	---	---	---	---	5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Hayre silty clay, poorly drained phase	---	---	---	---	---	---	---	---	---	---	---	---	---	---	40	60	---	---	---	---
Moline-Patent silt loams	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Moline-Patent clay loams	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Rhodes-Morton clay loams	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Banks loamy fine sand	10	20	5	10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Banks silty clay, poorly drained phase	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Alluvial loam soils, undifferentiated	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Alluvial clay soils, undifferentiated	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Bainville loam, hilly phase	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Bainville clay loam, hilly phase	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
McKenzie clay (poorer areas)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

See footnotes at end of table.

IRRIGATION 5

Soil ¹	Corn (grain) 100=50 bu.	Corn (fodder) 100=12 tons	Wheat 100=25 bu.	Barley 100=40 bu.	Oats 100=50 bu.	Alfalfa 100=4 tons	Sugar beets 100=12 tons	Beans 100=5 tons
Have silty clay	80	80	120	100	110	100	100	100
Have silty loam	80	80	120	100	110	100	100	100
Have fine sandy loam	70	70	100	90	95	90	90	90
Banks very fine sandy loam	55	60	85	75	55	80	75	75

¹ Soils are listed in the approximate order of their general productivity under the prevailing current practices.

² The soils are given indexes that indicate the approximate average production of each crop in percentage of the standard of reference. The standard represents the approximate average acre yield obtained without the use of amendments on the more extensive and better soil types of those regions in the United States in which the crop is most widely grown. Leaders indicate that the crop is not commonly grown on the soil. It should be realized that these indexes are largely estimates of judgment, as yield data by soil types are yet too fragmental to be adequate. Indexes in columns A represent the average yield, and those in columns B represent the average yield of the better years. In general, yields in columns A are assumed to be about 60 percent of those in columns B.

³ These indexes are based upon yields when alfalfa is first grown in the rotation. They do not take into account the detrimental effect that the continued growth of alfalfa has in the Great Plains on the supply of soil moisture for succeeding crops, including alfalfa.

⁴ The term "cow-acre-days" is used to express the carrying capacity or grazing value of pasture or range lands. It represents the number of days that 1 animal unit can be supported on 1 acre without injury to the pasture, or the product of the number of animal

units to the acre multiplied by the number of days. It is based on a rate 100 cow-acre-days, and 1 cow to 10 acres. Estimates are for normal seasons on which there is almost no grass. The indexes refer to yields obtained from sheep or goats. On semiarid grazing to each cow.

⁵ This classification indicates the prevailing practices of management for farming or grazing. It is based on the general classification to be used for farming or grazing. It is based on the maintenance of soil and soil fertility. The indexes refer to yields obtained from sheep or goats.

⁶ These are estimates based on probable Dedmire rotations and the use of proper practices in irrigated sections

in table 5 being largely estimates based on the experience and judgment of local farmers and other agricultural workers and members of the field party.

Certain slight differences are to be noted from the indexes assigned to similar soils in either McKenzie or Billings County. Some of the soils differ slightly in characteristics. Thus, the Havre soils of Morton County are considered more nearly like the Havre soils of McKenzie County than like those in Billings County that have developed from the alluvium of a smaller stream than the Missouri River. Others differ from similar soils in McKenzie County in the range of slope or in the frequency of scab spots, because of a difference in definition of the mapping units in terms of these characteristics in the two counties. Again, there appears to be a tendency for Billings County to experience slightly greater variability in crop yields and to be slightly more subject to adverse hot winds and slightly less rain fall than either Morton or McKenzie County.

In table 5 the indexes in column A indicate the estimated average yield and those in column B refer to the estimated average of the better years. Average yields, including seasons of partial and total crop failure, are probably not more than 60 percent of the yields obtained in the average favorable years. The soils are listed in the order of their general productivity under dominant current practices, and productivity grade numbers are assigned in the column headed "General productivity grade." The general productivity grade is based largely on the indexes for wheat in this spring-wheat region, although in the actual placements the indexes for the other crops are also recognized. Since it is difficult to measure mathematically either the exact significance of a crop in local agriculture or the importance and suitability of certain soils for particular crops, the placements are a result of inspection of the indexes and personal judgment rather than of precise mathematical computation. If the apparent average of the crop indexes for a soil type comes between 90 and 100, the soil type is assigned a grade of 1; if it comes between 80 and 90 a grade of 2 is given, and in this way other lower grades are assigned.

The column "Physical land classification" summarizes in a simple way the productivity and use capabilities of the various soils by placing them in a few groups on the basis of their relative suitability for dry farming and grazing.

Productivity tables do not present the relative roles that soil types, because of their extent and the pattern of their distribution, play in the agriculture of the county. The tables give a characterization to the productivity of individual types. They cannot picture the total quantitative production of crops by soil areas without the additional knowledge of the acreage of the individual soil types devoted to each of the specified crops.

Inasmuch as these ratings are based only on the characteristics of the soils and their productivity, they cannot be interpreted directly into land values except in a very general way. Distance to market, relative prices of farm products, and other factors influence the value of the land.

In connection with the use of the soil map as a basis for rural assessment for taxation, it may be stated that several of the units

shown on the published soil map represent, for purposes of simplification, combinations of rather similar units that were shown on the field sheets and that were used in arriving at the rating of each tract of land. In addition to comparative productivity, other factors that determined the relative rating of each unit area considered in the evaluation of land for assessment were distance to market, location in relation to other tracts, the size of the individual soil areas in respect to the feasibility of their cultivation, and present use. This productivity table, although similar to those set up for the assessment classification, cannot be considered identical with them.

GENERALIZED MAPS OF SOIL ASSOCIATIONS

The detailed soil map of Morton County shows the areal extent and geographic distribution of the soils and land types of the county; but in order that the map may be of use for practical objectives, the units of mapping must be interpreted in the light of the available information about them. The individual soil descriptions, the productivity rating section, the illustrations, and the section on Land Uses and Agricultural Methods, are all expressions of the effort to have the detailed soil map carry meaning for the readers of the map and report.

A large number of interpretative maps can be derived from the data of the detailed soil map. The color pattern of the detailed soil map, with its six major hues based primarily on the topographic positions occupied by the soils, is one kind of an interpretative map. Figure 2 also shows the distribution of the topographic features of the county but in much less detail. It is another interpretative map of a more generalized nature. Both types of maps have their advantages and disadvantages, depending upon the needs of the user.

Similarly, figures 3 and 4 are generalized maps that differ only in the degree of the detail that they show. They have both been drawn from the detailed soil map. Figure 3 gives the distribution of four generalized soil associations, whereas figure 4 shows the distribution of 10 generalized soil associations. Figure 4 exhibits greater detail in respect to both the geographical distribution of the soil associations and the number of the individual soil types and phases that are recognized. It is both more cartographically and more categorically detailed than figure 3 (15). With an increase in the number of soil associations recognized in a given area, such as shown in figures 3 and 4, the more precisely can each soil association be defined in terms of its constituent parts. In other words, each area of a particular association in figure 4 is more nearly like the other areas similarly designated than is true of the areas in figure 3. Figure 4 is therefore more nearly a soil association map because all of the areas of a soil association, as it is strictly defined, have a similar range of relief, a similar group of soils with approximately the same relative proportion of the various soil types and phases, and also the same pattern of soil distribution. Actually, however, the soil associations in both figures 3 and 4 are still very generalized, and individual areas differ considerably in respect to the kind and extent of the component soil types. For example, an area in figure 3 designated as belonging to the Morton-Flasher-Grail-Bainville-Williams association

may consist of only soils of the Morton, Flasher, and Bainville series, whereas another area of the same association may consist of only the Morton, Grail, and Williams soils and contain no areas of either the Flasher or the Bainville soils. The same situation holds for figure 4 except to a lesser degree. Reference to the detailed soil map will illustrate this point. Thus, several broadly generalized soil association maps could be prepared for Morton County. They would range from one with no areas delineated to one showing all the separations outlined on the detailed soil map. In fact, the two generalized maps in figures 3 and 4 were prepared from a more detailed and creditable one carrying 35 different soil associations, which is not included in this report, however, because of the difficulties of reproduction and ready interpretation. The added detail, largely categorical, made the areas of each respective association relatively uniform compared with those of the maps in figures 3 and 4.

Despite the limitations of the above-mentioned maps, they are included with this report because they serve to simplify and summarize briefly, generally, and graphically some of the information carried by the detailed soil map.

BROADLY GENERALIZED SOIL ASSOCIATIONS

Hall-Wade-Banks-Havre association.—This broad association of soils occupies the bottom lands and low terraces along the rivers and streams of the county. These areas are relatively smooth and free of stone and occupy the lowest elevations in the county. They are used principally for grazing, although a considerable acreage produces hay, corn, and other feed crops. Because of the several distinct kinds of soils included in this association, some of the areas differ widely from one another in respect to soil conditions. For example, areas of the Wade-Hall silty clay loams complex, principally along Muddy Creek, are characterized by a considerable development of claypan, whereas areas of Banks loamy fine sand, principally along the Missouri, Heart, and Cannonball Rivers, are comparatively loose and excessively drained. In figure 4 this association has been broken into the two associations Banks-Havre-Cheyenne and Hall-Wade-Cheyenne Huff.

Flasher-Patent-Moline-Rhoades association.—This association stands out rather distinctly in the southeastern part of the county and appears to be related to exposures of the Fox Hills sandstone geologic formation. The areas in general are relatively smooth, although some are definitely rolling, and presumably the landscape is older geologically than other parts of the county. The larger part of the land is used for grazing because of the rather common occurrence of unfavorable soil conditions for cultivated crops. The soils over most of the area are characterized by either sandy texture or claypans. The principal soils are Flasher loamy fine sand, smooth phase; Flasher fine sandy loam; Flasher loamy fine sand; Patent loamy fine sand; Patent-Moline fine sandy loams complex; Moline-Patent fine sandy loams complex; and Morton-Rhoades loams complex. Reference to figure 4 shows that no further break-down was made of these areas on that map.

Morton-Flasher-Grail-Bainville-Williams association.—This association is shown as covering a large part of Morton County and

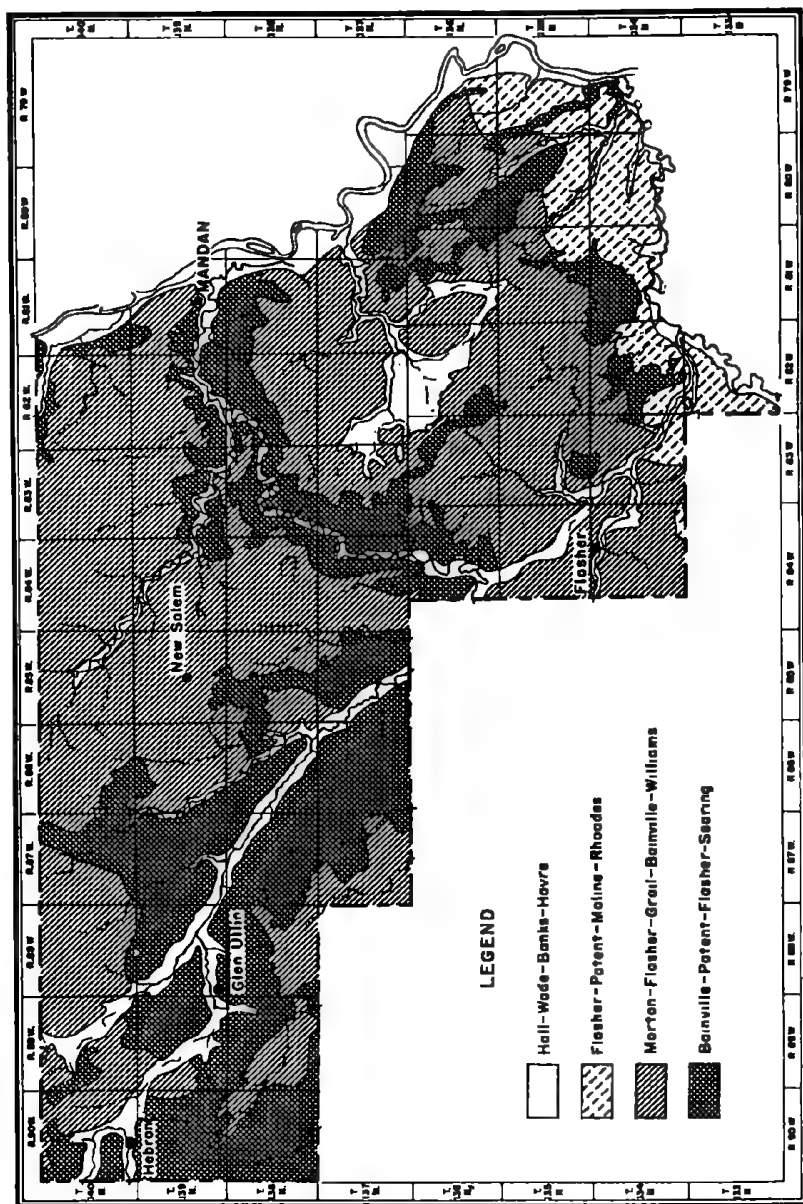


FIGURE 3.—Broadly generalized soil associations of Morton County, N. Dak.

includes most of the relatively high smooth uplands and the undulating and rolling uplands (see fig. 2). Broadly speaking, the landscape consists of a succession of undulating and rolling prairies, the monotony of which is broken here and there by wooded stream valleys bordered by steep slopes, isolated buttes, or morainic hills, and smooth ridge tops, plateaus, or tablelands of varying extent. This association includes a considerable part of the arable uplands of Morton County that

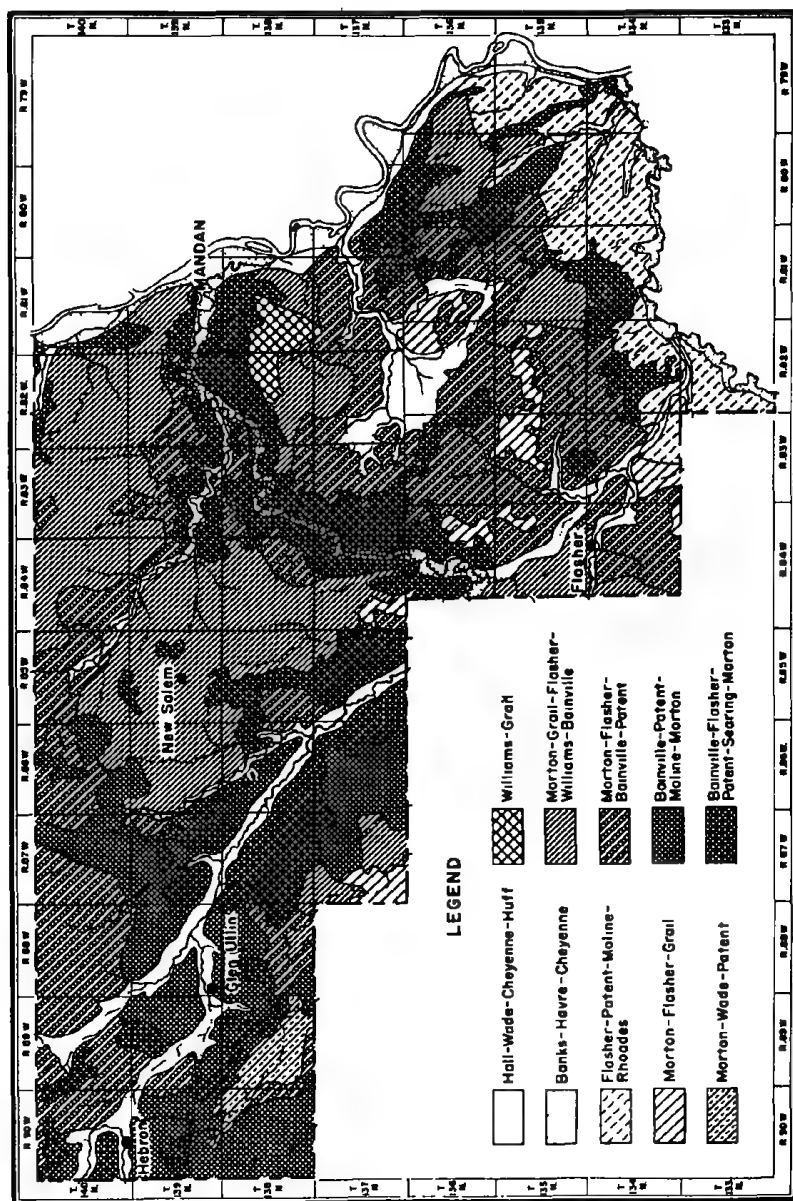


FIGURE 4—Generalized soil associations of Morton County, N. Dak.

are used to produce spring wheat, other small grains, and flax. Stoniness is one soil feature that limits the suitability of certain areas for cultivated crops.

The pattern or relative extent of the different members of this soil association is variable. For example, some areas consist essentially of Morton and Flasher soils, others of Morton and Grail, and others of Williams and Grail. These less extensive associations have been shown

in figure 4 as the Williams-Grail, the Morton-Flasher-Grail, the Morton-Grail-Flasher-Williams-Bainville, the Morton-Flasher-Bainville-Patent, and the Morton-Wade-Patent associations.

Bainville-Patent-Flasher-Searing association.—This association is nearly coextensive with the hilly and steep lands shown on figure 2 but it includes certain smoother areas that consist principally of the Bainville and Patent soils. Most of the area produces a sufficient cover of grass to provide grazing, although individual soil areas may be nearly bare. The rough topography affords some protection to livestock during winter storms.

As in the other soil associations, the relative proportions of the individual soil components vary from place to place. For example, the Searing soils and scoria outcrops are confined largely to the areas in the western part of the county and do not occur along the Heart River to any significant extent. Similarly, the proportion of Flasher soils is greater in some areas than in others. In figure 4 this association has been broken into the Bainville-Patent-Moline-Morton and the Bainville-Flasher-Patent-Searing-Morton associations.

GENERALIZED SOIL ASSOCIATIONS

The discussion of the following soil associations is limited largely to statements about the associated soils because the features of the landscape and land uses have been briefly given under the descriptions of the broadly generalized soil associations.

Hall-Wade-Cheyenne-Huff association.—This association is confined for the most part to the local streams instead of the valleys of the Missouri, Heart, and Cannonball Rivers. The Huff soils occupy the natural levees adjacent to the stream courses and also the tributary alluvial fans entering the valleys. The Hall soils and the Hall-Wade and Wade-Hall soil complexes occupy the greater parts of the valley floors. Their actual distribution varies from place to place, depending on the local environmental factors (largely related to drainage) that have determined the occurrence of scab spots and a claypan horizon. The Cheyenne soils occupy terraces that are underlain by sand or gravel and are rather widely scattered over the valleys outlined in figure 4, including a terrace along the Missouri River southeast of Schmidt.

Banks-Havre-Cheyenne association.—This association is located on the valley floors of the Missouri, Heart, and Cannonball Rivers. The Banks soils generally occupy the areas adjacent to the rivers. Along the Missouri River most of the area between the Bank soils and the upland bluffs or terrace fronts is occupied by the Havre soils, whereas along the Cannonball and Heart Rivers the Cheyenne soils are the principal associates. The Havre soils are generally well suited for irrigation farming, but the Banks and Cheyenne are generally too porous for the efficient use of water.

Flasher-Patent-Moline-Rhoades association.—The remarks under this heading on page 118 apply equally here, because no changes were made between figures 3 and 4 in respect to this association.

Morton-Flasher-Grail association.—This association is confined largely to the smooth tablelands in the southern part of the county,

where the principal soils are Morton loam, Morton clay loam, and Flasher fine sandy loam, with less extensive areas of Grail silty clay loam and Grail silt loam. In some places Morton loam is predominant, whereas in others Morton clay loam or Flasher fine sandy loam are the principal soils. These areas are among the more uniform and better suited areas for cropland in the county.

Morton-Wade-Patent association.—This association was recognized as a separate area in the western part of the county, principally in T. 138 N., R. 89 W., where it occupies a rather broad depression in the upland along the headwaters of Heart Butte Creek. Morton loam is the principal soil, but there are also sizable areas of the Wade-Hall and Hall-Wade complexes. The Patent soils are situated principally on the gentle slopes along the north border of the area.

Williams-Grail association.—This association occupies only one area—the Custer Flats, southwest of Mandan. This is a comparatively uniform tableland area dominated by Williams silt loam. It is the most uniform and productive upland area in Morton County for the common farm crops.

Morton-Grail-Flasher-Williams-Bainville association.—This association occupies relatively broad areas in the rolling northern and northeastern parts of Morton County. The Morton and Grail soils are associated with each other in all parts of the area and with the Williams soils in the northeastern part of the county, where the evidences of glaciation are most evident. The Flasher and Bainville soils occupy a smaller total area than the Morton and Grail soils, but they are similarly widespread in their distribution. The soil pattern varies from place to place in respect to the proportionate areas of individual soils, so that locally the Grail, Bainville, or Flasher soils may dominate individual 160-, 320-, or 640-acre tracts. Small areas of the Patent and Moline soils are also included.

Morton-Flasher-Bainville-Patent association.—This association in certain respects is similar to the Morton-Grail-Flasher-Williams-Bainville association, particularly in the general aspects of the landscape and the general suitability of the areas for farming. Certain soil differences exist, however, and require different farm management practices. For example, the degree of stoniness is commonly less, although certain specific tracts have just as excessive stoniness as any tracts in the Morton-Grail-Flasher-Williams-Bainville association. The relative proportion of the Flasher soils is greater, and hence the hazard of soil blowing is probably somewhat more acute. Likewise, the acreage of the Bainville soils and particularly of the Patent soils is greater, and as a result the management of light-colored heavy soils on slopes is a more extensive problem for the farmers in these areas than in the other association. As in other areas, differences in the proportionate amounts of the various soils exist, so that certain farms may be composed essentially of Morton and Flasher soils, others of Flasher-Bainville soils, others of Bainville-Patent soils, and still others of Patent-Bainville soils.

Bainville-Patent-Moline-Morton association.—This association consists principally of the Bainville and Patent soils with less extensive areas of the Moline and Morton soils. The areas are situated

in the western part of the county. Bainville loam; Bainville clay loam; Bainville loam, smooth phase; and Bainville clay loam, smooth phase are the main soils of the Bainville series, whereas Patent clay loam, Patent-Moline clay loams, and Moline-Patent clay loams are the principal representatives of the Patent and Moline soils and their complexes. The Morton soils are less extensive. The country is essentially rolling, with some steep slopes, and grazing and farming are both carried on.

Bainville-Flasher-Patent-Searing-Morton association.—This association consists essentially of hilly and steep lands that occur principally along the major streams or form highly dissected drainage divides, such as the area southwest of Glen Ullin. Steep phases of the Bainville and Flasher soils are the most extensive soil units. The remarks under the Bainville-Patent-Flasher-Searing association generally apply.

LAND USES AND AGRICULTURAL METHODS

A planned agricultural program for Morton County will involve the production of feed crops for livestock, the extensive grazing of animals for meat, and the limited production of cash crops. Because of the numerous crop hazards, only the most productive soils can be tilled profitably; and in order to maintain sufficient reserves of feed, much of their acreage must be devoted to feed crops. The remaining acreage may be considered as available for cash crops. The kinds of cash crops, however, are limited by both climatic and marketing conditions. The production of feed crops deserves the more serious attention of the farmers because of the hazards in crop production and the serious consequences to livestock farming if there is a shortage of feed.

During the period of settlement by homesteaders and the subsequent continued expansion brought about by the first World War and mechanized agriculture, tillage of soils spread rapidly over the county. Experience of recent years has shown that crops cannot be successfully produced on the less productive soils; and in the interest of the general welfare of the county isolated areas of even more productive soils should be turned over to meadow or grazing land.

Even under the best plan of operation, land operators in this section are confronted by crop and range hazards. A succession of years during which cash crops fail, feed reserves become seriously reduced, and grazing becomes sharply curtailed occur occasionally. Such a regional condition makes a demand on credit not experienced in more uniformly productive sections, and calls for an elastic low-cost though conservative plan of credit that will bridge these occasional unproductive periods and spread the financial burden over the more prosperous years.

Most of the soils that are suitable for crop production are in a fairly high natural state of fertility compared with those of the more humid sections of the eastern United States. They are well supplied with nitrogen and are sufficiently calcareous for the satisfactory growth of plants, such as alfalfa, that require relatively large quantities of lime. The natural fertility of these soils has decreased only slightly during the cropping history of the county, in spite of the facts that cash grain

crops are the main source of income and very little effort has been made to return plant nutrients to the soil through legume crops, barnyard manure, or commercial fertilizers. This relatively slow diminution is due, at least in part, to low average yields and to slow loss of plant nutrients through oxidation of plant residues. At some time in the near future, however, it is to be expected that the effect of continual tillage and removal of crops without return of plant nutrients to the soil, accompanied in places by erosion, and other physical difficulties intensified by drought conditions, will be reflected in a diminution of yields. Lower yields will be noticed first on the less fertile soils; in fact, such a trend has already begun.

Phosphorus is probably the most nearly deficient of the plant nutrients. It has been definitely determined that the regular application of phosphate fertilizer is advantageous to most crops produced on irrigated areas of western North Dakota. Its use on dry-farmed areas is as yet questionable, because a lack of available moisture limits yields to such a low figure as to make the probable return on money invested in fertilizer of this sort extremely low. Barnyard manure, however, can be used to good advantage even on the dry-farmed areas. The usual practice is to spread the comparatively small available supply of manure on the stubble land in winter or early spring. Some farmers assert that light applications worked into summer-fallowed land, or otherwise thoroughly incorporated with the soil, give justifiable returns, and experiments conducted at the United States Northern Great Plains Field Station indicate increased yields where barnyard manure was used (19).

Operators on dry-farmed areas probably influence the productivity of their soils more through their treatment of soil structure and tilth than through their treatment of soil fertility, drainage, or any of the other soil-productivity factors. The natural structure of the more productive soils of this county is very suitable for plant growth—much better in fact than in soils of more humid sections—and it is recognized that the productivity of these soils is jeopardized by the destruction of this natural structure. Continuous tillage breaks the natural fragments of clods to a fine or nearly single-grained condition, making the soil mass considerably more subject to wind and water erosion, and by destroying the natural vesicles, or air channels, it makes the soil less well aerated. Another detrimental effect of tillage is the development in certain soils of a hardened layer, or plow sole, $1\frac{1}{2}$ to 3 inches thick just below the plow layer. Observations, particularly of fine sandy loam and loam soils, indicate that the use of moldboard plows for a long time develops this hard, dense plow sole. This condition interferes with the movement of soil moisture and the growth of plant roots. The productivity of these soils very probably would be enhanced by subsoil tillage that would break up the plow sole. The cost of such an operation, however, will be an important item in determining its practicability.

The farmer, recognizing the general desirability of maintaining natural soil structure, however, is faced by the unavoidable necessity of seedbed preparation and crop cultivation. The nearest approach to the most desirable condition is to follow a cultural system that provides sufficient tillage for satisfactory crop growth with implements designed to disturb as little as possible the natural structure (2) and

to cover or turn under only partly the surface sod or stubble. Leaving a roughened surface containing bits of stubble and other vegetation tends to check soil blowing and in fall-plowed areas tends to form catch basins for snow. Three of the recommended types of implements are the duckfoot cultivator, the one-way disk plow, and the rotary-rod weeder.

Most of the silty clay loam and clay soils have their tilth improved by fall plowing, as the natural weather conditions in winter slake, or soften, the hard chunks and clods; but fall tillage may be detrimental even to these soils because of increased blowing. On the other hand, the retention of snow is an advantage not to be overlooked. In general, silty clay loams and clays are much less subject to damage by soil blowing in winter as a result of fall plowing than are loams and sandy loams. The so-called claypan soils have their productivity improved by tillage over a period of years. Improvement here is due to the breaking up of the claypan and the distribution and incorporation of the more loamy surface layer of the interspot areas with the less productive clay of the clay spots; but tillage of these soils should be moderate and only sufficient for the accomplishment of this purpose.

The presence of excessive amounts of salts, so-called white alkali, practically eliminates some soils from consideration for crops requiring tillage under present agricultural conditions in the dry-farming section of the county. The possibility of salt intrusion and accumulation deserves particular attention on areas that may be irrigated from the creeks and drains whose sources of water are local. In contrast, the water from the Missouri River is more satisfactory in respect to its salt content. Of course, its application on poorly drained soils will tend to bring about an accumulation of soluble salts.

Although a great many of the soils have inherent characteristics favorable to a high productivity for dry farming, many of the characteristics of the environment are distinctly undesirable and seriously discount the otherwise high productivity of the soils. These are principally lack of sufficient moisture during the growing season, hot periods during midsummer, winds of high velocity, hail, black stem rust, and insect pests. Lack of sufficient moisture is considered the primary limiting factor in crop production in this county. Selection and diversification of crops, selection of improved varieties, and cultural and rotation methods are the most effective means of coping with the above-mentioned hazards. Diversification of crops reduces the chances of total crop losses. For example, a season that may result in a total loss of the wheat crop may be comparatively favorable for corn or millet. Selection of crops involves the choosing of those that have a comparatively low water requirement and are either drought-resistant or early maturing. Thus, the small grains—rye, wheat, and barley—are early maturing, and corn, sorghum, flax, and millet are at least moderately tolerant of dry periods. Most of these crops have been improved by the development of new varieties and by varietal research by the North Dakota Agricultural Experiment Station and other stations, in regard to weather, disease, and insect hazards. Further information on the varieties of cereal crops adapted to the soils of Morton County may be obtained from the bimonthly bulletin of the North Dakota Agricultural Experiment Station for September 1940 (18). This article contains complete information on the results of long-time

tests of oats, emmer, flax, barley, and corn varieties. A summary of wheat varieties at the Dickinson substation is contained in the bi-monthly bulletin for January 1940 (17).

The hazards of crop production in counties such as Morton have been called to the attention of the public in recent years by the occurrence and recurrence of drought, dust storms, grasshoppers, rust, and low prices. Weather data indicate that the recent droughty years are only a part of a cycle of comparatively wet and dry years. Variations in moisture from year to year make it impossible to recommend standard or fixed systems of crop rotation. In fact, flexibility is a prerequisite of a rotation. Again, practices of land use and soil management suitable for the wetter part of the cycle proved to be unsuited or even detrimental for the drier years. Thus, the number of soil types that may be safely cultivated in the wetter years is reduced in the drier years. Practices of management necessarily are changed. For example, summer fallowing was much more successful before than during the recent droughty years. Of course, changes in the structure and organic-matter content of soils, with continued tillage, may be partly responsible; but differences in climate from year to year also contribute, and with the return of wetter seasons the use of fallow strips will be more common. The following experimental data and recommendations are offered, with the realization that they do not apply to all soil types and in all years.

A common and suitable rotation for this section, according to recommendations of the United States Northern Great Plains Field Station, is a 3-year rotation of corn, wheat, and oats or barley. As corn seldom occupies as much as one-third of the acreage on many farms, summer fallow should be practiced on the rest of this one-third. The primary object of including either an intertilled crop or summer fallow in the rotation, in a region of low rainfall where drilled or broadcast small grains occupy an important part of the acreage, is to keep down the growth of weeds and thereby conserve the moisture for the benefit of the crop to follow. For this purpose summer fallow is more efficient than growing intertilled crops, as the growth of weeds is more thoroughly suppressed, the acre cost of tillage is lower, and a moisture reserve is built up to the benefit of the following year's crop, at least during its early stages of growth. The growing of an intertilled crop, however, has the marked advantage of producing a crop during the same season that the weed-control measures are in operation. According to information from the Northern Great Plains Field Station, a rotation including summer fallow followed by wheat yielded 21 bushels of wheat an acre, whereas a rotation including corn followed by wheat yielded 25 bushels of corn, plus forage, and 17 bushels of wheat. Other crops that can be successfully used in this part of the rotation are sorghum and potatoes.

The most satisfactory grasses for seeding are crested wheatgrass, western wheatgrass, brome grass, and slender wheatgrass. Brome grass tends to become sod-bound, and slender wheatgrass is not very long-lived. Sweetclover is used for both hay and pasture. Alfalfa is generally a hay crop that is not suited to grazing. Western wheatgrass is not commonly seeded, but on some of the clay loam soils it frequently reestablishes itself if given an opportunity to do so before the roots of the native sod have been completely killed by tillage.

It is the most desirable native grass for hay meadows. Sweetclover is a biennial, but if allowed to develop sufficient seed it will reseed itself, making at least a partial stand in later years. It is suitable for both hay and grazing; but as a hay crop on areas suitable for alfalfa the yields are not so high as those of alfalfa. Sweetclover as a pasture crop is a good supplement to crested wheatgrass, as it affords comparatively good midsummer grazing at a time when crested wheatgrass is dormant.

It should be recognized that deep-rooted legumes, such as alfalfa and sweetclover, draw heavily on the soil moisture. Therefore these crops, especially, alfalfa, should be seeded in areas where sufficient moisture has a chance to accumulate. Farmers report that in parts of the Great Plains crops following alfalfa fail completely because of a depletion of soil moisture.

Crested wheatgrass, according to Technical Bulletin 307 (23), is especially well adapted to the northern Great Plains, as it is suitable for both hay and pasture and is hardier than alfalfa, which is a somewhat hazardous crop, owing to its susceptibility to winterkilling. Alfalfa, however, is probably the most satisfactory hay crop on the most productive soils, as the yields are much larger than those of crested wheatgrass and the chances of maintaining a stand on these desirable areas are comparatively good. Crested wheatgrass, however, is probably the most satisfactory crop for establishing a permanent meadow or a grazing crop on at least the better areas of those unproductive soils that should be removed from tillage. According to Department Bulletin 1301 (19), it is a very desirable grass for early spring and fall grazing, but it should be supplemented by a pasture crop better adapted to midsummer grazing, such as sweetclover or deferred native pasture, that is, pasture that has not been grazed early in the season, in order to provide grazing for livestock through midsummer when the crested wheatgrass is likely to be injured.

The most satisfactory method of establishing stands of these hay and grazing crops is to prepare the land by summer fallowing or by growing an intertilled crop. Alfalfa and sweetclover are seeded either with or without a nurse crop; but the best stands, according to Department Bulletin 1301 (19), are obtained where no nurse crop is used. The other hay and pasture crops should be seeded without a nurse crop.

Although these and some other forage plants are of great value to the agriculture of this section, the problem of reestablishing a good grazing crop in places where the native stand of grass has been destroyed by tillage, particularly on the sandy and the less fertile soils, has not yet been solved satisfactorily.

Because of the danger of losing stands of these more permanent hay and grazing crops as a result of winterkilling, dry weather, and other hazards, it is necessary to have some annual forage crops on which to rely. Millet, small grains cut before maturity, sorghum, Sudan grass, and corn are the most satisfactory for this purpose.

The stand of native vegetation on many areas, according to observations of cattlemen and investigators, has suffered considerably from overgrazing, particularly in recent years. This practice has either thinned or killed much of the more edible vegetation, and the growth of weeds has increased proportionately. As a result, both the carrying

capacity and the quality of the grazing vegetation on such areas has been markedly reduced. Generally, the native vegetation will re-establish itself if grazing is curtailed sufficiently.

Grazing experiments (16) on an area composed predominantly of Williams silt loam and Arnegard silt loam were conducted at the United States Northern Great Plains Field Station near Mandan for several years, starting with 1915. These trials demonstrated the results of different rates of continuous grazing and a system of deferred and rotation grazing. Two-year-old steers and a 5-month grazing period starting from May 15 to June 1 and continuing until October 15 to November 1 were used. The deferred and rotation system of grazing was designed to allow each division of the pasture to mature a crop for 2 successive years before it was grazed by the cattle in the fall of each year. Grazing on each division was deferred and rotated, so that each unit had an equal chance to produce a maximum crop normally before it was disturbed. Following are some of the conclusions drawn from the results of these experiments, as set forth in Department Bulletin 1170 (16):

The measure of efficiency of a pasture or system of grazing is not determined by one factor but by several of equal importance.

The most efficient system of grazing is one that will insure sufficient forage during the entire season to produce the greatest total gain in weight with the least number of cattle on the minimum unit of land without permanent injury to the native vegetation. The requirements of this measure of grazing efficiency are most nearly fulfilled by the deferred and rotation system of grazing.

Native pastures deteriorate when grazed because of (1) too early grazing in the spring, (2) continuous grazing, and (3) overgrazing. All of these factors can be controlled.

The 70-acre pasture, grazed at the rate of one steer to 7 acres, provides approximately the area of land required to produce the maximum gains per head under a system of continuous grazing. The 50-acre pasture, grazed at the rate of one steer to 5 acres, is not large enough to allow the cattle to make maximum gains per head. This pasture is overgrazed. Under a system of deferred and rotation grazing the number of acres required per head is reduced to between 4 and 5. This acreage will provide enough feed to allow the cattle to make gains per head intermediate between those made in the 50-acre pasture and those made in the 70-acre and 100-acre pasture. This system allows the maximum utilization of the vegetation without the injury to it accompanying overgrazing.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of weathering and soil development acting on the parent soil material deposited or accumulated by geologic agencies. The characteristics of the soil at any given point depend on (1) the physical and mineralogical composition of the parent material; (2) the climate under which the soil material has accumulated and has existed since accumulation; (3) the plant and animal life in and on the soil; (4) the relief, or lay of the land; and (5) the length of time the forces of development have acted on the material. The climate and its influence on soil and plants, depends not only on temperature, rainfall, and humidity, but also on the physical characteristics of the soil or soil material and on the relief, which, in turn, strongly influences drainage, aeration, runoff, erosion, and exposure to sun and wind.

Morton County is near the eastern border of the Chestnut soil zone (6, 13). The climate is distinctly continental. The summers are comparatively short, hot, and dry, and the winters are comparatively long and cold. The mean temperature for the three summer months is about 67° F., and the maximum is about 107°. Freezing conditions prevail within the ground for about 4½ months of the year. The total precipitation from April 1 to November 1 is about 12.8 inches. The average winter precipitation from November 1 to April 1 is less than 3 inches. Ground moisture very seldom becomes abundant enough to cause complete percolation through the soil, with the result that the material at a depth of 3 feet is in a comparatively dry condition most of the time.

A great part of the county was covered by one of the early ice advances (10, 11), but till, deep enough to serve as the parent material for soils, occurs only in scattered areas in the northeastern quarter of the county. The till for the most part is olive-drab fairly friable calcareous clay containing some pebbles and a variable quantity of boulders. The soils of the remaining part of the county, except those on stream alluvium, have developed from unconsolidated or only slightly consolidated olive-drab or olive-gray clay, grayish-yellow silt, and olive-drab sand of the Fort Union, Lance, and Fox Hills formations. Most of these materials are calcareous when treated with an acid, except occasional layers, which occur particularly in the southeastern part of the county. Beds of consolidated soft sandstone and hard flintlike shale are commonly associated with the less consolidated clays, silts, and sands. The shale beds are seldom more than 2 to 3 feet thick, but the soft sandstone layers reach a thickness of several feet. Most of the materials of these formations are fresh-water laid, but a part of the Lance formation, known as the Cannonball marine member, is of marine origin. Lignite beds varying in thickness from a fraction of an inch to several feet are common throughout most of the fresh-water-laid formations and particularly throughout the Fort Union. Lignite beds in the Fort Union formation elsewhere in the State are known to be as much as 35 feet thick. Beds of scoria are common in a section of the county between New Salem and Glen Ullin. This material is composed of pinkish or reddish angular shale fragments that have been formed from the baking of clay beds by the burning of underlying lignite layers. Scoria gives rise to or influences the development of the Searing soils of this area, but the lignite beds themselves do not appear to have contributed anything directly to the characteristics of any of the soils.

The native vegetation on the zonal soils of Morton County consists principally of short grasses. Blue grama is by far the dominant short grass on the fine sandy loams, loams, and clay loams. Buffalo grass is common but not abundant. It is the dominant grass, however, on the scab spots of the solodized-Solonetz complexes that have been sufficiently rejuvenated to have a surface layer free of sodium clay to a depth of at least a few inches. Taller grasses, such as western wheatgrass on clay loam and clay soils, western needlegrass on the loams, and sandgrass on the sandy soils, are common. A small quantity of big bluestem grows where moisture conditions are more favorable than the average, and saltgrass is abundant on all Solonchak and most

solodized-Solonetz areas. Other grasses common to the area are little bluestem, porcupinegrass, feathergrass, prairie junegrass, Kentucky bluegrass, squirreltail, quackgrass, northern redgrass, and slender wheatgrass. Niggerwool and other sedges and sandgrass, the sandgrass generally occurring in dense patches, are the dominant vegetation on most areas of the sandiest soils of the uplands.¹⁸ Gray sagebrush buffaloberry, and buckbrush are common on sites suitable for their development. Practically all of the tree and brush vegetation is confined to the bottom lands, draws, and favorable spots on north-facing steep slopes. Cottonwood, ash, and elm on the bottom lands and ash and elm on the favorable sites in the uplands are the most common trees. Cottonwood grows to a diameter of as much as 3 feet, but other species seldom attain a diameter of more than 8 or 10 inches.

The most important characteristics of the Chestnut soils are (1) a dark to very dark grayish-brown friable surface layer that is faintly eluviated, (2) a layer below this having a dark grayish-brown color and a well-developed prismatic structure, and (3) a light-colored or grayish material in the upper part of which is a moderate accumulation of carbonates at a depth of about 16 inches. The color of the zonal soils in the county gradually becomes lighter from east to west. The darkest solum is on Custer Flats, a broad, smooth ridge lying south of Mandan, capped by several feet of glacial till. The lightest colored zonal solum is in the vicinity of Hebron in the extreme western part of the county.

The Williams series represents the Chestnut soils developed from glacial till. Stream dissection has resulted in an irregular, uneven, and broken covering of till. The distribution of the areas of Williams soils is therefore irregular, but most of them are on the broader, smoother ridge tops, and all of them are east of New Salem and north of a line drawn from New Salem southeastward to the Little Heart River. In contrast with the Morton series, which represents the normal Chestnut soil developed from sedentary material of the Fort Union and Lance geologic formations and the areas of which are distributed throughout the county, the color of the solum of the Williams soils averages slightly darker. Following is a description of Williams silt loam taken at the west edge of SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 34, T. 139 N., R. 83 W.

0 to 1½ inches, dark to very dark grayish-brown silt loam, well bound in place by a mat of grass roots. When the mat is broken and crushed the soil falls away easily as fine soft fragments that are easily crushed to a powdery fine crumblike mass. This horizon has a pH value of about 6.8.

1½ to 5 inches, as the grass roots become less plentiful, the soil mass becomes more firm. The soil comes from place as dark to very dark grayish-brown fragments that are firm but crush easily with some brittleness to a crumbly or semipowdery mass. There is very little difference between the color of the powdered and the uncrushed material. The upper inch or so shows no very well-defined vertical breakage, but the lower part breaks readily to coarsely prismatic pieces. The upper 2 or 3 inches in places show a platy arrangement of the soil aggregates. These aggregates have a distinctly flattened outline and are about ⅙ to ⅓ inch in thickness and from ⅓ to ⅙ inch wide. The pH value of the soil of this horizon is about 6.5.

¹⁸ For further study of the correlation of grassland types in western North Dakota, refer to the publication, *Characteristics of Major Grassland Types in Western North Dakota* (3).

- 5 to 12 inches, at this depth the color becomes noticeably lighter and the prismatic structure well defined. The material comes from place as dark grayish-brown or dark-brown silt loam or clay loam elongated prisms. These prisms are from $\frac{3}{4}$ to $1\frac{1}{4}$ inches in diameter and are roughly cylindrical. When shaken vigorously they break along smooth horizontal surfaces into nutlike fragments. The numerous fine roots extending vertically through the prisms hold these nutlike fragments in place, thus preserving the prismatic shape until the roots are deliberately broken. The nutlike fragments can be broken with little difficulty along the less well defined vertical and horizontal cleavage cracks to small vertically elongated prismlike fragments. Generally the downward-facing surface of a prism fragment is slightly darker than the adjoining upward-facing surface, a characteristic common to the horizontal surface of fragments of the claypan layer of most or possibly all solonized soils. Close examination of the broken surface of prism fragments shows a faint vesicular character and a variable number of fine rootlet channels. The pH value of the material of this horizon is about 6.7.
- 12 to 17 inches, this layer for the most part is a softer and more friable olive-drab silt loam with a prismatic structure that grades from good in the upper part to coarse and ill defined in the lower part. The average diameter of the prisms ranges from $1\frac{1}{4}$ to 2 inches, and the pieces are less firm and brittle. The color change actually begins at a depth of about 10 inches, but it is so gradual that the olive-drab color is not well established at a depth of less than 14 inches. Some effervescence takes place when the soil is treated with acid at a depth of about 16 inches. The average pH value of the material of this horizon is 7.1.
- 17 to 20 inches olive-drab friable clay loam containing numerous soft white flecks of calcium carbonate ranging in diameter from $1/50$ to $1/10$ inch and occasionally more. This layer has a definite vertical breakage or fair prismatic structure. The nutlike fragments are well formed but are not as firm or brittle as those of the 5- to 12-inch layer. Rootlets are numerous but less abundant than in the horizons above. A few small gravelstones are distributed throughout the material. The pH value of the material of this horizon is about 8.1.
- 20 to 38 inches, olive-gray or creamy-gray friable clay loam. This layer contains an abundance of soft white flecks of calcium carbonate, especially in the central portion. The mass crumbles easily, and only a faint prismatic or nut structure is evident. When treated with acid the entire mass effervesces. The pH value of the material of this horizon is about 8.4.
- 38 to 50 inches, this material is similar to that of the layer above except that the white flecks of calcium carbonate are less abundant and there is no evidence of vertical breakage or prismatic structure. The mass color is more nearly olive drab, and there are occasional yellow streaks and specks of limonite or related forms of hydrated iron. Gravelstones and occasional boulders are distributed throughout. This material represents the comparatively unaltered parent glacial till. The pH value of the material of this horizon is about 8.7.

This particular soil profile is not as dark in the surface layers as some of the Williams soils farther east in the county, but it is somewhat darker than the Morton soils, especially those in the western part of the county. In general, the color of the surface layers of this profile is about average for these two major representative series of the Chestnut soils in Morton County. Some areas of the Williams soils, particularly those east of the vicinity where the above soil description was observed, have the dark grayish-brown to very dark grayish-brown color extending to a depth of from 8 to 12 inches. The depth to calcium carbonate in the Williams profile described above is about average for the Morton soils, but for much of the Williams and for some of the Morton soils, particularly those of the eastern part of the county, the depth to calcium carbonate ranges from 18 to 24 inches or more. There are a few areas of Morton soils in the western part of the county that

appear to be developed from material that had a comparatively smaller quantity of carbonates in them. In such areas the depth to carbonates is greater and the zone of lime accumulation is less well marked.

The Hall soils on the terraces are noticeably darker than the average Williams soil. Moreover the color change from east to west is less marked than it is from the most easterly Williams to the most westerly Morton. The depth to calcium carbonate, as determined by effervescence when the mass is treated with acid, ranges from about 15 to 23 inches in the most westerly part to from 16 to 30 inches in the most easterly part. The Hall soils are commonly regarded as Chernozems. Their association with Chestnut soils in Morton County suggests conditions favoring more abundant moisture and more vigorous plant growth than is common to the uplands. Differences in materials and subirrigation by seepage water from the adjacent uplands may explain their darker color.

The Cheyenne series represents mature dark grayish-brown to brown soils that have developed on gravelly and sandy old alluvium of stream terraces. The profile features, except for the underlying parent materials, are similar to those of the Morton series. A visible accumulation of calcium carbonate is evident in places on the surface of the stones of the upper edge of the gravel stratum and the lower edge of the solum.

The sandier soils that have developed under the usual zonal conditions on the well-drained smooth to hilly and steep uplands are classified as members of the Flasher series. They are more nearly brown or less dark than the Morton or Williams soils. They have little or no prismatic structure, and the depth of the surface brown layers above calcium carbonate varies greatly. Effervescence frequently takes place at or near the surface on knobs or other exposed places of the hilly uplands, whereas smooth areas seldom show effervescence above a depth of 26 inches and generally none takes place at a depth of less than 40 inches.

The difference in depth of the solum of the soils in these two different positions suggests the rather wide range of conditions covered by the Flasher soils as they have been mapped. The material of the fine sandy loam types to a depth of about 15 inches comes from place as irregular, firm, brittle, angular fragments that are fairly easily crushed under pressure to a fine-crumb or nearly single-grained mass. Although a vertical breakage or prismatic structure is seldom developed in the fine sandy loam, an incipient structure is more evident than in the loamy fine sand.

The Bainville series represents those soils the characteristics of which have been markedly influenced by having been developed on a drier or more arid site than the normal zonal one. The common position is on marked slopes or on decidedly rounded knobs. These positions favor a greater loss of moisture by runoff and evaporation. Consequently, there is less vegetation and less soil development. Moreover, on such sites geologic erosion has more nearly kept pace with the soil-forming processes. The profile of the Bainville soils differs from that of the zonal Chestnut profile in having (1) a shallower solum, (2) a much less distinct soil structure, (3) a much shallower depth to abundant carbonates, and (4) in many places a lighter color throughout the solum.

Following is a description of the dark-colored variation of Bainville loam, smooth phase, taken from the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 12, T. 140 N., R. 83 W.

- 0 to 1 inch, dark to very dark grayish-brown loose mulchlike loam bound into a mat by an abundance of grass roots.
- 1 to 6 inches, dark to very dark grayish-brown loam grading with depth to grayish-brown loam. This layer has a fairly well defined prismatic structure similar to that of the regional Chestnut soil. The soil is friable and crushes easily to a fine-grained mealy mass.
- 6 to 12 inches, dark-gray or very light grayish-brown silt loam containing numerous white flecks of calcium carbonate. There is a semblance of prismatic structure, and the soil comes from place in nutlike fragments or blocks that are brittle but easily crushed to a fine-grained mass. Grass roots, though not abundant, are numerous enough to hold the fragments weakly together. Carbonates are abundant throughout this layer and the layers below.
- 12 to 18 inches, light-gray somewhat vesicular silt loam containing a great abundance of carbonates. The soil comes from place in soft lumps weakly bound together by grass roots.
- 18 inches +, below this depth is the laminated material of the comparatively unaltered beds of the Lance geologic formation. It is composed of laminations and varves of olive-gray clay, yellowish and rusty-brown silt, and very fine sand. This material in place is firm and digs out in angular laminated fragments, which break with brittleness under moderate pressure to a fine-grained mass.

The above description indicates that the color of the surface layer is as dark as that of the surface layer of the zonal Williams or Morton soils and also that there is a marked abundance of carbonates at a depth of about 12 inches. The markedly rapid gradation in color from the surface layer to the layer below suggests a tendency toward Rendzina. There is a notable acreage of this kind of Bainville loam in Morton County; but there are other areas, particularly on the more marked slopes, where the surface layer is a grayish-brown rather than a dark or very dark grayish-brown color, and where the carbonates, though plentiful and somewhat nearer the surface, are less strikingly abundant. This latter profile is comparable to the Bainville soils as they are in Billings County, N. Dak.; the profile of the detailed description, because of its strikingly dark but shallow solum and markedly high content of carbonates immediately below, suggests a rendzinalike condition. The Arnegard and Timmer soils are developed under local conditions that stimulate a more humid climate. Their occurrence in well-drained depressions of the gently rolling uplands favors a greater than normal moisture supply and the accumulation of soil material from the dark surface layers of the surrounding and higher lying soils. The very dark grayish-brown color generally extends to a depth of more than 16 inches, the prismatic structure is very well developed, and the depth to carbonates is generally more than 28 inches. These soils are the most productive of the county. The underlying silty and clayey materials serve to distinguish the Arnegard from the Timmer soils, which are underlain by sandier materials.

The Searing soils are Chestnut soils developed from scoria or material containing an abundance of scoria. Their acreage is small, and they are more variable than the Morton and Williams soils. The color of the solum has inherited to a marked degree the reddish color of the parent scoria. The 5- to 6-inch surface layer is dark to

very dark reddish-brown friable silt loam. Below this is reddish-brown silt loam. This horizon has a fair but very seldom well-developed prismatic structure. The depth at which carbonates are sufficient to cause effervescence when the mass is treated with acid varies considerably, but it is seldom at less than 25 inches below the surface. The scoria fragments themselves are free of carbonates, but generally carbonate incrustations are on their surfaces, and evidently have been precipitated from underground moisture rising from underlying clay and silt beds.

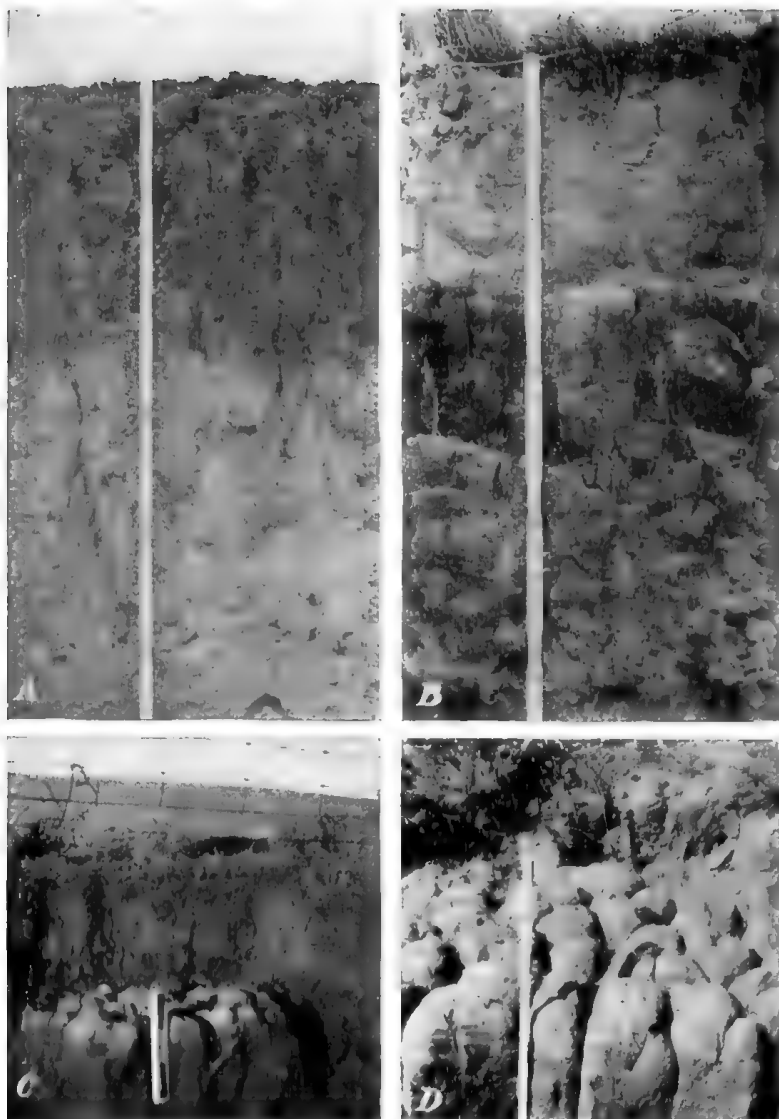
The Grail soils are the very dark to dark grayish-brown soils developed on gentle alluvial or alluvial-colluvial slopes. The soil material has lain undisturbed by fresh deposition and rewashing for a sufficient period of time to permit the development of zonal characteristics, including a dark surface, distinct prismatic structure, and the segregation of some calcium carbonate. In fact, moisture conditions have been slightly more favorable than on the uplands for the growth of grasses, and the Grail soils may be grouped with the Arnegard, Timmer, and Hall soils as exhibiting characteristics bordering on those of the Chernozem soils. The Grail soils are somewhat darker in Morton County than they are in Billings County, where their total area is comparatively small.

The position and parent materials of the soils of the Patent series are similar to those of the Grail series, but their parent materials are of more recent origin and the regional soil-forming processes have not been able to develop the zonal Chestnut profile. Consequently, the Patent soils, in contrast with the Grail soils, are lighter colored in the surface soil, have a shallower solum and a less distinct prismatic structure, and calcium carbonate is at or near the surface.

The Huff series includes the soils that occupy the alluvial fans and natural levees and have carbonates sufficient to cause effervescence at or within a few inches of the surface. The color of the surface layer of the soils is rather variable from place to place and ranges from dark grayish brown to light brown. In general, the Huff soils of Morton County average a darker brown than those in Billings County. This darker color may be explained by one or more of the following interrelated conditions: (1) The darker color of the parent materials derived from wash from the associated soils of the uplands, such as the Williams and Grail, as compared with the lighter color of the Morton and Patent soils of Billings County; (2) the more stable and older character of the alluvial fans and natural levees in Morton County; and (3) the climatic forces tending to produce darker soils in Morton County.

The Cherry soils are on stream terraces in positions comparable to those on which the Hall and Cheyenne soils are situated. The general character of the soil profile in respect to the color of the surface layer and the presence of carbonates at or near the surface is similar to that of the Patent soils; the Cherry soils, however, exhibit a more distinct prismatic structure.

Considerable areas of soils in this county are or have been more or less affected by salts. These soils are included in the Moline, Rhoades, Wade, and McKenzie series. They are in positions that allow, or did allow at one time, the movement of salt-laden water into the soil.



A, Characteristic profile of normal Chestnut soil, like the Morton. Note grass roots and platy structure of the topmost 3 inches, prismatic structure of the main body of dark soil, and zone of accumulated lime below. **B**, Characteristic profile of solodized-Solonetz soil, like the Rhoades. Note the platy light-colored surface soil over dark heavy columnar material. **C**, Columnar soil in the B horizon of solodized-Solonetz. **D**, Close-up view of columns.

According to the general scheme of evolution of Solonchak, Solonetz, and Soloth soils (5), the development of the Moline, Rhoades, and Wade soils has been dominated by salt-laden capillary water, and the development of the McKenzie soils has been dominated by salt-laden floodwaters. The most common locations of those soils influenced predominantly by capillary water are on broad benches along streams or on gentle valley and upland slopes. Most of those developed under the influence of flooding by saline water are on old pond sites or alluvial fans.

All the soils developed under the influence of salt-laden capillary water present an extremely spotted or pocked appearance—a condition due partly to differences in the quantities of salt intrusion and removal and partly to differential wind and water erosion of the eluviated surface layers.

The Solonchak represents the first stage in the development of the Solonchak-Solonetz-Soloth evolution. The process under which the Solonchak develops is salinization, in which excess soluble salts, some of which generally are sodium salts, accumulate. Solonchak soils are characterized by their lack of a definite structure and profile differentiation.

If drainage conditions improve, the excess soluble salts are removed, but the sodium ions are usually sufficient to dominate the colloids so that they become dispersed. The soil becomes highly alkaline through hydrolysis of the exchangeable sodium to sodium hydroxide. Organic matter becomes dispersed and distributed over the other soil particles. Dense columnar structure, high alkalinity, and low content of soluble salts characterize the Solonetz soils, and the processes involved are desalinization and alkalization, collectively called solonization.

As soon as the colloids become dispersed they tend to move downward, to produce surface horizons lighter in color and lower in clay content. This process is known as solodization and leads to the development of the Soloth. Actually most of the so-called Solonetz, or claypan, soils described in this report are solodized-Solonetz soils and have a platy friable and nearly white surface layer overlying the dense intractable columns forming the claypan. Figure 5 illustrates the development of these different types of intrazonal soils.

Plate 14 illustrates the columnar structure that is a dominant feature of solodized-Solonetz soils.

There are four groups of these soils in Morton County, the development of each of which has been influenced by imperfect drainage and consequent salt intrusion. They are, in order of their extent, (1) a solodized-Solonetz complex, which is composed of differentially eroded and comparatively uneroded areas, (2) a solodized-Solonetz-Solonchak complex, (3) a Solonetz, and (4) a Soloth. In addition, some of the areas of the solodized-Solonetz-Solonchak complex are very nearly entirely Solonchak. As stated above, the solodized-Solonetz complex is by far the most extensive. It is characterized by scab spots in the differentially eroded areas, whereas other less extensive areas are free of scab spots. Commonly it is situated on very gently sloping alluvial valley slopes and nearly level second bottoms or stream terraces. Less extensive areas are distributed through the uplands where local conditions have favored their development. Different kinds of solodized-Solonetz complexes based on the character of the associated

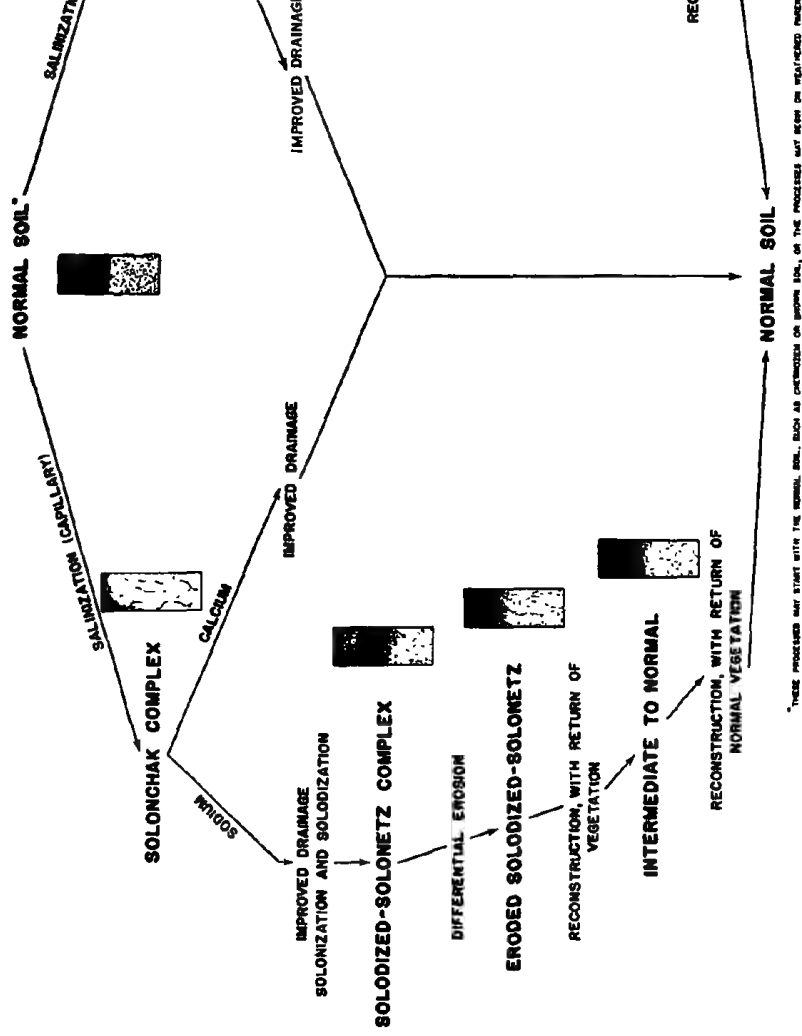


FIGURE 5.—Evolution of Solonchak, Solonetz, and Soloth soils (

soils, topographical position, and intensity of development are recognized in the mapping of the Morton-Rhoades, Rhoades-Morton, Bainville-Rhoades, Rhoades-Bainville, Grail-Moline, Moline-Grail, Patent-Moline, Moline-Patent, Hall-Wade, and Wade-Hall complexes. For example, the Morton-Rhoades complex consists of the same soils as the Rhoades-Morton complex and occupies the same relative position in the landscape. The principal distinction between these two complexes is in the number of scabby spots and the degree of claypan development. In other words, the Rhoades-Morton complex exhibits differential erosion to a much greater degree and the claypan is more common than in the Morton-Rhoades complex. The most extensive acreage and the most uniform development of the differentially eroded solodized-Solonetz complex occur in the areas of the Moline-Patent complex.

The surface of the Moline-Patent clay loams complex is very gently sloping. Surface drainage is good, but subdrainage is slow. It is uneven or bumpy, as it is composed of numerous shallow depressions of irregular or roughly circular outline and intervening low hummocks or swells that give the landscape a choppy or rippled appearance. The eroded pits or depressed clay spots, locally known as scab spots, lie from 4 to 10 inches below the general surface of the intervening or interspot part; they range from about 2 to 15 feet or more in diameter and occupy from 25 to 70 percent of the surface. The scab-spot areas are generally poorly grassed, but the interspot areas (consisting chiefly of uneroded Moline clay loam but including some Patent clay loam) almost invariably support a good cover of blue grama (pl. 10). The scab spots generally support a scant cover of western wheatgrass and weedlike plants during moist seasons, and during average seasons they support a sparse cover of small pricklypear, gumweed, and saltgrass. The oldest scab spots, that is, those that have been rejuvenated considerably as a result of solodization and an accompanying increase in mesophytic vegetation since the blow-out or erosion period, support a fair to good stand of buffalo grass.

Following is a description representative of Moline clay loam in the interspot part of the eroded solodized-Solonetz complex that was included in the mapping of Moline-Patent clay loams (SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 138 N., R. 90 W.).

- 0 to 2 $\frac{1}{2}$ inches, dark olive-brown silt loam with a strikingly well-developed platy structure. Carefully crushed, the platelets break apart. They are from $\frac{1}{100}$ to $\frac{1}{50}$ inch thick and about $\frac{1}{15}$ inch wide. They crush easily, but with brittleness, to a powdery mass, the color of which is noticeably lighter gray than the surface of the fragments. This material has a pH value of about 5.8.
- 2 $\frac{1}{2}$ to 6 inches, dark olive-brown silt loam with a semblance of platy structure. The material, however, comes from place as massive pieces that are not inclined to break to the platelets. Under pressure the massive fragments crumble easily, but with brittleness, to a powdery or fine-grained condition. The material of this horizon has a pH value of about 5.3.
- 6 to 9 inches, dark-gray brittle silt loam that breaks easily to irregular nut-sized fragments. This material is still a part of the solodized or eluviated layer, but it has a vertical breakage or cleavage that is a remnant of the columnar structure that this portion of the profile had before the solonized condition was replaced by the development of the solodized condition. The pH value of this horizon is about 6.2.

- 9 to 14 inches, the upper part of the solonized or claypan layer. The color grades rapidly (but in this case not sharply) from the light color of the solodized layer above to the dark color of this solonized layer. There is a well-defined breakage or cleavage plane between these two layers, the breakage coming a little above the upper limit of the dark-colored solonized layer and thereby leaving a thin irregular layer of light-colored material attached to the solonized material. Immediately below the thin light-colored material is very dark-gray or nearly black hard dense clay. This color extends to a depth of about half an inch. Below this is dark olive-drab hard dense clay. There is no vertical cleavage, and the entire layer is a hard mass that offers considerable resistance to breakage. The pH value of the material of this horizon is about 7.4.
- 14 to 18 inches, dark olive-drab hard dense clay that breaks under pressure to sharply angular fragments. This material breaks to fragments more easily than the material of the layer above, but nevertheless it is hard and is worked to a powdery mass only with considerable difficulty. The pH value of the material of this horizon is about 7.7.
- 18 to 38 inches +, olive-drab clay containing numerous white flecks of salt crystals. The mass is quite hard but is not solonized. The salt crystals in this particular exposure do not effervesce, but in most areas calcium carbonate is abundant in this sublayer. The material throughout this layer is hard, but less so in the lower than in the upper part. The pH value of the material of this layer is about 7.5.

There are several characteristic variations in the solums of the soils of the interspot areas of this complex. Generally the solodized layers grade abruptly to the solonized layer with the platy structure extending to within a fraction of an inch of the solonized material. In these areas there is no semblance of a columnar layer within the solonized part of the solum. Another very common and characteristic variation applies particularly to the solonized layer. In these areas the solodized layer changes abruptly to the solonized layer, separated only by a very thin layer or film of nearly white powdery very fine sand or silt. The upper surface of the solonized layer has a cobbled or biscuitlike appearance. Some of the nearly white silt or very fine sand of the film clings firmly to this surface and gives it a white or frosted appearance. Much of this white material can be removed by brushing the surface with a brush or a broom. Each one of the biscuit tops, or caps, is the upper surface of a column that extends down through the solonized layer, the entire mass of which is composed of these columns. The columns in turn consist of very dark olive-brown or nearly black dense hard clay similar to the solonized material of the above-described profile. These columns are from $\frac{1}{4}$ to nearly 3 inches in diameter and are resistant to breaking. The largest columns are developed in more sandy material, the texture of the solonized layer in such areas averaging fine sandy clay loam rather than clay. Under pressure the columns break to small hard angular cubelike fragments, the diameters of which almost invariably are only a part of that of the column. The smaller columns are more easily broken to fragments than the large ones, as the latter are massive and seldom have natural interior cleavage surfaces. The larger columns also vary in color and hardness from the outside inward. The outer one-fourth inch is the darkest and the hardest part; the innermost part is dark olive-brown material that is considerably less hard. Specimens of these large columns have been observed to have flecks of carbonates in the innermost material.

Following is a description of a truncated profile in a scab spot of Moline clay loam, the interspot part of which is described above.

- 0 to 1 inch, olive-gray semicrust of silt and very fine sand that crushes with weak brittleness to a powdered condition. Close examination of a fragment shows a platy structure and a pumicelike vesicular character. Some of the bubblelike air pockets are one twenty-fifth of an inch in diameter.
- 1 to 4 inches, very dark grayish-brown hard dense clay. The upper surface of this layer is finely pebbled or cobbled, but there is no columnar structure. Irregular cracks extend downward into the layer, and the mass under pressure breaks along them to very hard small angular pieces.
- 4 to 11 inches, dark olive-brown hard clay that breaks easily to angular fragments. There are a few salt flecks distributed through it. This layer may be partly solonized, but at least it is distinctly less so than the layer above.
- 11 to 18 inches +, this layer is similar to that above except that it breaks to coarser fragments, the material is more friable, and salt flecks are more abundant. Some of these salts are carbonates, as evidenced by very mild effervescence when the mass is treated with acid. Below a depth of about 15 inches olive-drab clayey material containing an abundance of carbonate flecks is not uncommon, particularly in solonized soils developed on alluvial flats.

An example of a comparatively uneroded solodized-Solonetz is furnished by Morton-Rhoades loams complex in the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 29, T. 134 N., R. 83 W. The surface is smooth, well grassed, and unbroken by the bare spots and microrelief so characteristic of the eroded solodized-Solonetz. To a depth of 12 to 14 inches the soil is similar to that of the average Morton loam except that platy structure is more noticeable in the upper 4 inches. At this depth there is a sharp contact with the claypan, and the characteristic pebbled, or biscuitlike, surface of the claypan is covered by a thin grayish powdery film.

Patent loamy fine sand to the extent that it has an incipient claypan may be considered to be an uneroded solodized-Solonetz. This soil represents the development of an incipient claypan in a very sandy soil. The surface is smooth, well grassed, and unbroken by the clay spots and microrelief characteristic of the eroded areas of solodized-Solonetz. The description of this soil in the section on Soils gives the important features of its profile. The more distinguishing features are (1) the decidedly sandy texture of the entire solum, (2) the considerable depth to the claypan, (3) the distinct light color of the 3- or 4-inch layer directly above the claypan, and (4) the lack of distinct columnar structure of the claypan.

Most solonization and subsequent solodization takes place in soils derived from fine-textured parent materials. There is, however, a limited acreage of comparatively sandy soils (the Patent-Moline fine sandy loams and the Moline-Patent fine sandy loams) in which a solonized layer has developed. Where the parent material averages fine sandy clay loam the columns are large and more massive than described above. The solonized layer is commonly less deep than that of the average solonized layer of the finer textured soils, and its color is not so dark. The contrast between the solodized and the solonized layers of the sandy soils is more striking than in the finer textured soils. The 1½-inch surface layer is generally dark grayish-brown fine sandy loam. This grades to light grayish-brown loamy

fine sand. The lower inch or two, which is the lightest colored part of the solum, is loose or nearly structureless, whereas the upper parts are weakly brittle. This loose grayish sandy material lies directly on the dark hard solonized layer.

The solodized-Solonetz-Solonchak complex is inextensive as compared with the aggregate area of the solodized-Solonetz complex. Practically all of the areas are on the broader alluvial clayey flats or benches along the interior streams of the county and are included in areas mapped as Hall-Wade and Wade-Hall complexes. These areas in general are represented on the map by salt symbols. Observable surface conditions indicate that the sites on the average are more poorly drained and consequently are more favorable for the accumulation of salts than those on which the eroded solodized-Solonetz complex occurs. The surface has a bumpy or gently choppy microrelief, and the bumps or swells are generally known as puff spots. They have a smoothly rounded surface and rise from 4 to 12 inches above the adjoining depressed or concave parts. These puff spots ordinarily occupy from 25 to 50 percent of the ground area, but in some areas they occupy well over 50 percent of it. The dominant vegetation on the puff spots is a good stand of saltgrass and in places an abundance of seepweed. The inter-puff-spot areas generally support a good cover of mixed blue grama and saltgrass.

The puff spots are predominantly Solonchak in character; that is, the greater part of the soil mass has a marked excess of sodium salts and consequently has a friable, mealy consistence. A great many of these spots, however, have a semblance of either solodization or solonization, or both, in the surface inch or two. Generally the surface half inch is a grayish-brittle vesicular crust of highly leached siliceous very fine sand or silt. Below this is generally a thin weakly and variably solonized layer, from 1 to 1½ inches thick, of grayish-brown to very dark grayish-brown hard clay or silty clay. Below this the material grades to distinctly salinized material. Below a depth of about 5 inches is very dark-gray very friable fine granular clay containing an abundance of salt flecks, which in many places give the appearance of a mass of white mycelia distributed through the soil mass. The material is easily dug from place and breaks easily into soft lumps. It is almost invariably moist and kneads easily to a plastic mass. Generally a large part of the salts are not carbonates. The interpuff-spot parts are for the most part decidedly solonized, although solonization is not as well developed as in the interspot areas of the solodized-Solonetz complexes. Columns and column caps are less well defined, and the solodized layer that is almost invariably present is less strikingly developed and does not extend to as great a depth. The leached, or solodized, condition is generally too weakly developed to cause this material to be subject at the present time to the development of blow-outs, which have given rise to the pitted condition of the eroded solodized-Solonetz complex.

The McKenzie series represents a Solonetz that has not been materially degraded by solodization. This series is developed on old pond sites or on other very nearly level alluvial clay depressions. The surface is free of the rippled or pocked microrelief so characteristic of the extensive differentially eroded solodized-Solonetz. During dry periods

there is generally a very thin grayish siliceous vesicular brittle crust on the surface. This is seldom more than half an inch thick. Below it is nearly black, very dark gray, or gun-metal colored hard dense clay. A few areas, however, have a surface layer that is friable enough to a depth of about 6 inches to permit tillage when moisture conditions are favorable. This clay mass of the dense horizon comes from place in large very firm chunks that are very resistant to further breakage. There are not sufficient carbonates to cause significant effervescence when the mass is treated with acid, although there are some specks of calcium carbonate that give a visible reaction. This material extends to a depth varying from 14 to as much as 40 inches. Below it the color becomes more gray and there are some salt flecks and crystals, a few of which effervesce. During dry periods the surface 20 inches or so is dry but the material below a depth of 20 to 30 inches generally is slightly moist. It is generally a little more friable either because of the slightly greater quantity of moisture or because of the greater quantity of calcium carbonate.

The solum of this soil, down to where there is a noticeable quantity of moisture, is thoroughly checked or cracked into blocks ranging in diameter from $1\frac{1}{2}$ to 3 feet. Under extremely dry conditions the cracks are as much as 3 inches wide. When this soil becomes thoroughly moist the cracks are closed by the swelling of the clay and the soil material becomes a sticky, stiff, plastic mass.

A variation of McKenzie clay with a gray surface layer represents areas of McKenzie clay that have been markedly degraded by solodization. This variation has been included with the McKenzie soils because of geographical association and similarity in respect to position and parent materials. The profile differs significantly, however, in that it represents the Soloth instead of the Solonetz condition.

The surface layer of 5 to 6 inches is gray or dark-gray silt loam, the uppermost part of which is somewhat darker than the remaining part of the layer. Generally it has a well-developed platy structure and the mass crumbles easily to a crumby or powdery mass. Below this layer the dark hard dense clay of the regular McKenzie clay is abruptly encountered. Carbonates are seldom found above a depth of 16 to 18 inches.

As previously indicated, the profile of this variation, which represents the Soloth condition, as well as that of the representative type of McKenzie clay, is comparatively uniform, and no microvariations of relief or profile comparable to the blow-outs or pits of the solodized-Solonetz complex or the puff-spot development of the solodized-Solonetz-Solonchak complex exist.

Areas of the first bottom lands have been classified and shown on the soil map as members of the Havre or the Banks soil series, as undifferentiated alluvial soils of sandy, loam, or clay texture, or as Riverwash. The Havre and Banks soils, like all those of bottom lands that are subject to occasional or frequent inundation, do not exhibit significant zonal profile features and are therefore designated as azonal soils. The following common features emphasize their azonal character: (1) Sufficient calcium carbonate throughout the profile to cause effervescence when treated with acid, (2) no zone of calcium carbonate accumulation, (3) a friable consistence throughout

the profile, and (4) the absence of any distinct development of textural, structural, and color profiles.

The Havre series includes the first bottom soils the sublayers of which are for the most part silty clay. The Banks series includes the first bottom soils the sublayers of which are sandy. The Havre soils, particularly the finer textured types, show a faint development of prismatic soil structure as evidenced by vertical breakage. As indicated by the following description, it is evident that at times conditions have been sufficiently stable for the soil to accumulate a considerable quantity of organic matter in what, during those periods, was the surface layer. The Banks soils, particularly the coarser textured types, have a recognizable though weakly developed color profile. Following is a description of Havre silty clay, the most important of the first bottom land soils. The description is of a profile examined in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 31, T. 138 W., R. 80 W.

- 0 to 2 inches, when moist, olive-gray silt loam that can be worked easily to a soft crumbly mass.
- 2 to 9 inches, friable silty clay loam that is dark olive gray when moist, but finely variegated very dark gray, light gray, and a very little light yellow when in an uncrushed dry condition. The soil comes from place in subangular fragments that have almost a nutlike structure. The pieces crush easily to a soft crumbly mass. There is a semblance of vertical breakage or structure, but laminations of deposition are also plainly visible.
- 9 to 13 inches, friable silty clay loam, finely variegated dark gray and light gray with a considerable quantity of yellow specks. When moist, the color is very dark grayish brown. Deposition laminations are more evident than in the layer above.
- 13 to 14 $\frac{1}{2}$ inches, very fine sandy loam to very fine sandy clay loam, yellowish gray with thin streaks of limonite yellow. The material comes from place as very weak-structured fragments, and the thickness of the lamination varies considerably.
- 14 $\frac{1}{2}$ to 25 inches, very dark olive-brown silty clay with thin gray laminations. It breaks to subangular fragments that are easily crushed. The laminations of deposition are strikingly evident.
- 25 to 30 inches, slate-gray silty clay that breaks readily into sharp definitely angular hard flattened lamination fragments ranging in size from $\frac{1}{20}$ to $\frac{1}{4}$ inch in diameter. The material digs from place easily as a loose mass of these pieces. When dug they are very resistant to pulverization, and when moistened they develop a soggy surface and are resistant to the absorption of moisture.
- 30 to 44 inches +, olive-drab or olive-gray soft and friable silty clay containing a few white carbonate flecks.

The entire profile effervesces abundantly when treated with acid. The comparatively darker color of the 9- to 13-inch layer and the 14 $\frac{1}{2}$ - to 25-inch layer evidently represents periods during which these layers accumulated a considerable quantity of organic matter while in the position of the surface soil.

The very fine sandy loam is the most representative of the Banks series. The surface material to a depth of from 8 to 12 inches is grayish-brown to dark grayish-brown very fine sandy loam. The soil comes from place in brittle chunks or fragments that crush fairly easily to a fine-grained mass. This layer grades to loose olive-gray fine sand.

Observations at the present time indicate that the sandier first-bottom soils had a predominantly deciduous forest cover, whereas at least parts of the finer textured soils were occupied by grasses, sedges, and shrubby growth.

Table 6 gives the pH determinations of several of the more important soils in Morton County.

TABLE 6.—*pH determinations of several samples of soils from Morton County, N. Dak.*¹

Soil type and sample No.	Location	Depth	pH value
		<i>Inches</i>	
Morton loam			
352239.....	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec 2, T 138 N, R 90 W.....	0 - 6	6.4
352240.....		6 - 14	6.3
352241.....		14 - 18	6.7
352242.....		18 - 30	8.1
Moline clay loam			
352247.....	NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec 8, T 138 N, R 90 W.....	0 - 2 $\frac{1}{2}$	5.8
352248.....		2 $\frac{1}{2}$ - 6	5.3
352249.....		6 - 9	6.2
352250.....		9 - 14	7.4
352251.....		14 - 18	7.7
352252.....		18 - 26	7.6
352253.....		26 - 38	7.3
Moline fine sandy loam.			
352265.....	NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec 32, T 135 N, R 80 W.....	0 - 1 $\frac{1}{2}$	6.2
352266.....		1 $\frac{1}{2}$ - 4	6.5
352267.....		4 - 6	7.6
352268.....		6 - 8 $\frac{1}{2}$	8.6
352269.....		8 $\frac{1}{2}$ - 16	8.3
352270.....		16 - 20	8.9
352271.....		20 - 25	8.2
Flasher fine sandy loam.			
352281.....	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec 21, T 134 N, R 83 W.....	0 - 4	6.6
352282.....		4 - 7	6.4
352283.....		7 - 14	6.5
352284.....		14 - 42	6.8
352285.....		42 - 60	7.0
352286.....		60 - 65	7.4

¹ pH determinations made by E. H. Bailey, assistant soil technologist, Division of Soil Survey, Bureau of Plant Industry, Soils, and Agricultural Engineering.

The mechanical analyses of several soils are given in table 7.

TABLE 7.—*Mechanical analyses of samples of several soils from Morton County, N. Dak.*

Soil type and sample No	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	<i>Inches</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Williams silt loam								
352206.....	0 - 1 $\frac{1}{2}$	0.4	0.8	1.1	4.9	14.4	55.3	23.1
352207.....	1 $\frac{1}{2}$ - 6	.6	.7	.7	3.6	13.5	50.5	30.5
352208.....	6 - 13	3	.7	1.0	4.0	15.1	47.4	31.5
352209.....	13 - 17	.3	.5	.6	2.8	15.1	48.1	32.5
352210.....	17 - 26	.6	.6	.5	2.6	24.3	44.3	27.1
352211.....	26 - 31	5.1	3.4	3.3	10.9	16.7	26.9	33.7
352212.....	31 - 47+	1.0	1.3	2.9	14.2	15.7	28.6	36.3
Moline clay loam								
352247.....	0 - 2 $\frac{1}{2}$.5	.9	1.8	6.9	8.1	44.4	37.3
352248.....	2 $\frac{1}{2}$ - 6	.4	.6	1.5	5.9	8.0	44.1	39.5
352249.....	6 - 9	3	.5	1.3	5.1	7.3	46.1	39.4
352250.....	9 - 14	.2	.5	1.0	4.4	7.3	43.2	43.4
352251.....	14 - 18	1	.3	.6	1.6	2.1	41.8	53.4
352252.....	18 - 26	0	.2	.5	1.9	4.7	42.7	50.1
352253.....	26 - 38	.1	.2	.5	2.0	5.9	39.7	51.7
Flasher fine sandy loam								
352281.....	0 - 4	.2	2.1	13.7	49.4	10.5	10.4	13.6
352282.....	4 - 7	2	2.0	11.0	48.2	11.7	10.7	16.1
352283.....	7 - 14	3	2.4	13.8	50.3	11.8	7.0	14.4
352284.....	14 - 42	1	1.7	9.9	49.7	15.1	9.6	13.9
352285.....	42 - 60	0	1.5	10.8	59.6	13.2	3.5	11.5
352286.....	60 - 65+	2	1.2	13.0	62.8	10.1	3.5	9.1

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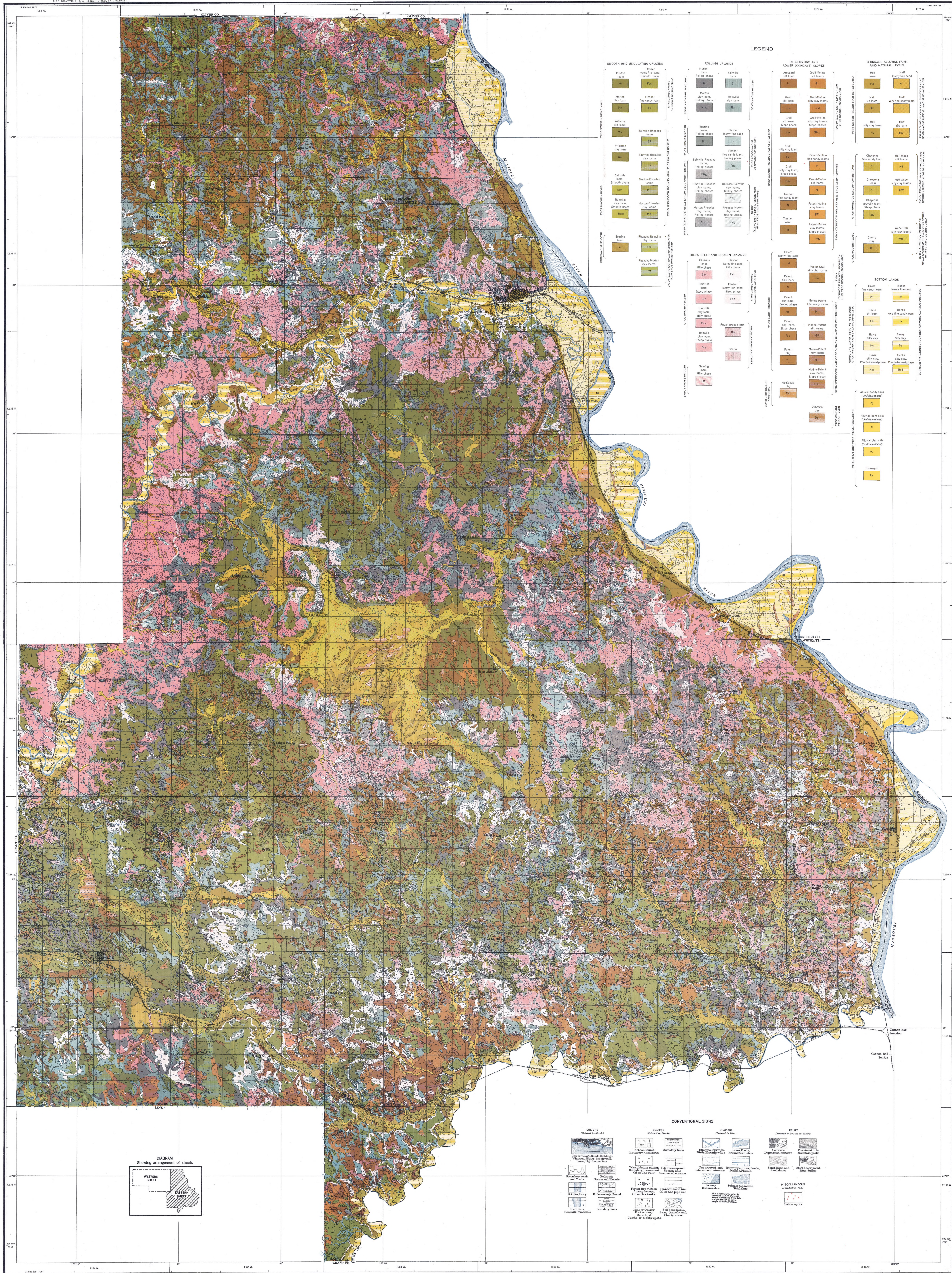
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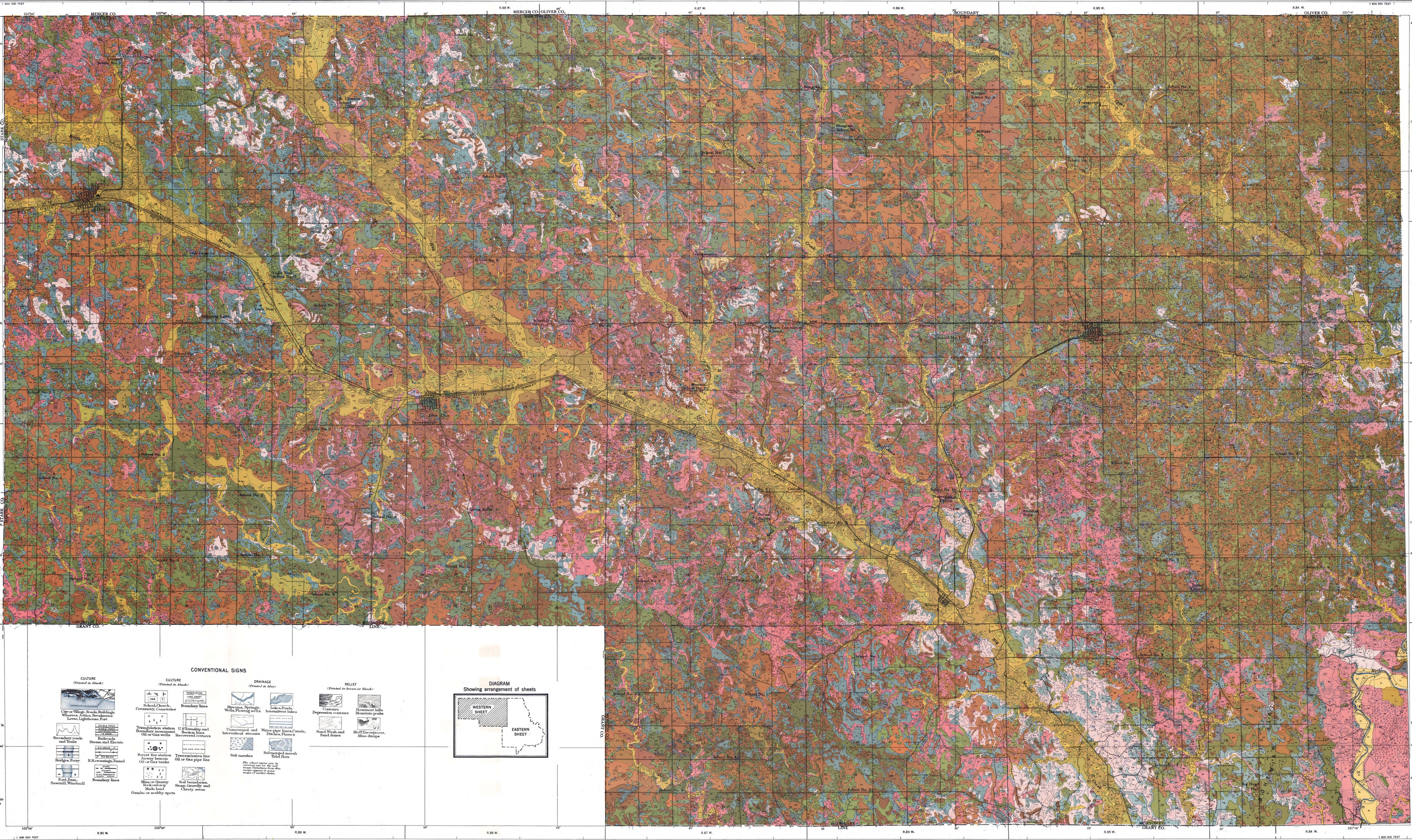
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DEPRESSIONS AND LOWER (CONCAVE) SLOPES

BOTTOM LANDS

ROLLING UPLANDS

HILLY, STEEP AND BROKEN UPLANDS

TERRACES, ALLUVIAL FANS, AND NATURAL LEVES

MISCELLANEOUS